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CONTENTS

Part 1. March 18, 1940.

PAGE

1. The Breeding Behavior of the Common Shiner, *Notropis cornutus* (Mitchill). By EDWARD C. RANEY. (Plates I-IV; Text-figure 1)..... 1
2. Divergence and Probability in Taxonomy. By ISAAC GINSBURG 15
3. Miscellaneous Notes on the Eggs and Young of Reptiles. By ROGER CONANT & ALEXANDER DOWNS, JR..... 33
4. Occlusion of the Venom Duct of Crotalidae by Electro-coagulation: an Innovation in Operative Technique. By DUVAL B. JAROS. (Text-figure 1) 49
5. Eastern Pacific Expeditions of the New York Zoological Society. XVII. A Review of the American Fishes of the Family Cirrhitidae. By JOHN TEE-VAN. (Plate I; Text-figures 1-4) 53
6. Eastern Pacific Expeditions of the New York Zoological Society. XVIII. On the Post-embryonic Development of Brachyuran Crabs of the Genus *Ocypode*. By JOCELYN CRANE. (Text-figures 1-8)..... 65
7. New Species of British Guiana Heterocera. By W. SCHAUS.. 83
8. A Papillary Cystic Disease Affecting the Barbels of *Ameiurus nebulosus* (Le Sueur), Caused by the Myxosporidian *Henneguya ameiurensis* sp. nov. By R. F. NIGRELLI & G. M. SMITH. (Plates I-VIII; Text-figure 1) 89
9. Caudal Skeleton of Bermuda Shallow Water Fishes. IV. Order Cyprinodontes: Cyprinodontidae, Poeciliidae. By GLORIA HOLLISTER. (Text-figures 1-17)..... 97
10. The Histology of the Eye of the Cave Characin, *Anoptichthys*. By E. B. GRESSER & C. M. BREDER, JR. (Plates I-III)113

Part 2. July 3, 1940.

11. Plankton of the Bermuda Oceanographic Expeditions. IX. The Bathypelagic Caridean Crustacea. By FENNER A. CHACE, JR. (Text-figures 1-64)117
12. Eastern Pacific Expeditions of the New York Zoological Society. XIX. Actiniaria from the Gulf of California. By OSKAR CARLGREN. (Text-figures 1-8).....211
13. Morphological and Embryological Studies on Two Species of Marine Catfish, *Bagre marinus* and *Galeichthys felis*. By DANIEL MERRIMAN. (Plates I-V; Text-figures 1-9)221

	PAGE
14. Propagation of the Electric Impulse Along the Organs of the Electric Eel, <i>Electrophorus electricus</i> (Linnaeus). By C. W. COATES, R. T. COX, W. A. ROSENBLITH & M. VERTNER BROWN. (Plate I; Text-figures 1-3).....	249
15. Notes on the Display Forms of Wahne's Six-plumed Bird of Paradise. By LEE S. CRANDALL. (Text-figures 1-3).....	257
16. Acute Hemorrhagic Gastro-enteritis in a Giant Panda. By LEONARD J. GOSS.....	261
17. Two New Species of Trematodes from the Deep Sea Scorpion Fish, <i>Scorpaena madurensis</i> Cuv. & Val. By ROSS F. NIGRELLI. (Plate I; Text-figures 1 & 2).....	263
18. Report of the Hospital and Laboratory of the New York Zoological Park, 1939. Mortality Statistics of the Society's Collection. By LEONARD J. GOSS.....	269

Part 3. November 14, 1940.

19. Eastern Pacific Expeditions of the New York Zoological Society. XX. Medusae of the Templeton Crocker and Eastern Pacific <i>Zaca</i> Expeditions, 1936-1938. By HENRY B. BIGELOW. (Text-figures 1-20)	281
20. Two New Species of Trematodes (<i>Apharyngostrigea bilobata</i> : Strigeidae, and <i>Cathaemasia nycticoracis</i> : Echinostomidae) from Herons, with a Note on the Occurrence of <i>Clinostomum companulatum</i> (Rud.). By O. WILFRED OLSEN. (Plate I)	323
21. Nesting of the Sunfish, <i>Lepomis auritus</i> (Linnaeus), in Tidal Waters. By NEIL D. RICHMOND. (Plate I)	329
22. Eastern Pacific Expeditions of the New York Zoological Society. XXI. Notes on Echinoderms from the West Coast of Central America. By HUBERT LYMAN CLARK. (Plates I & II; Text-figures 1-4)	331
23. The Nesting Behavior of <i>Eupomotis gibbosus</i> (Linnaeus), In a Small Pool. By C. M. BREDER, JR. (Plates I & II; Text-figures 1 & 2)	353
24. Reproductive Activities of a Hybrid Minnow, <i>Notropis cornutus</i> \times <i>Notropis rubellus</i> . By EDWARD C. RANEY.....	361

Part 4. December 31, 1940.

25. Eastern Pacific Expeditions of the New York Zoological Society. XXII. Mollusks from the West Coast of Mexico and Central America. Part I. By LEO GEORGE HERTLEIN & A. M. STRONG. (Plates I & II)	369
26. On the Electric Powers and Sex Ratios of Foetal <i>Narcine brasiliensis</i> (Olfers). By C. M. BREDER, JR., & STEWART SPRINGER	431

	PAGE
27. A Study of the Activities of a Pair of <i>Galago senegalensis moholi</i> in Captivity, Including the Birth and Postnatal Development of Twins. By FLORENCE DE L. LOWTHER. (Plates I-VI)	433
28. Diets for a Zoological Garden: Some Results During a Test Period of Five Years. By HERBERT L. RATCLIFFE.....	463
29. The Biology of the Smoky Shrew (<i>Sorex fumeus fumeus</i> Miller). By W. J. HAMILTON, JR. (Plates I-IV; Text-figure 1)	473
30. Social and Respiratory Behavior of Small Tarpon. By ARTHUR SHLAIFER & C. M. BREDER, JR. (Plates I & II; Text-figure 1) ..	493
31. New Observations on the Blood Group Factors in Simiidi and Cercopithecidae. By P. B. CANDELA, A. S. WIENER & L. J. GOSS.....	513
32. Muscle Dystrophy in Tree Kangaroos Associated with Feeding of Cod Liver Oil and Its Response to Alpha-Tocopherol. By LEONARD J. GOSS.....	523
33. Mortality Statistics for Specimens in the New York Aquarium, 1939. By ROSS F. NIGRELLI. (Plates I-III)	525
34. A Comparison of Some Electrical and Anatomical Characteristics of the Electric Eel, <i>Electrophorus electricus</i> (Linnaeus). By R. T. COX, W. A. ROSENBLITH, JANICE A. CUTLER, R. S. MATHEWS & C. W. COATES. (Text-figures 1-7) ..	553
Index to Volume XXV.....	563

ZOOLOGICA

SCIENTIFIC CONTRIBUTIONS OF THE NEW YORK ZOOLOGICAL SOCIETY

1.

The Breeding Behavior of the Common Shiner, *Notropis cornutus* (Mitchill).

EDWARD C. RANEY

*Zoology Department, Cornell University,
Ithaca, New York*

(Plates I-IV; Text-figure 1).

Although several authors have written concerning the habits of the common shiner, *Notropis cornutus* (Mitchill), there is little detailed information available on the breeding behavior of this widely distributed cyprinid. The more pertinent papers giving data on spawning are those by Adams & Hankinson (1928), Greeley (1927 and 1929) and Hankinson (1932). The author has made an intensive study of the breeding habits of the common shiner, *Notropis cornutus cornutus*, during the past spring (1939) in the region about Ithaca, New York, and these data, together with observations made elsewhere mostly during the previous four years, are presented here. The breeding act has been observed many times at various places and under different conditions. However, the details were obscured, as they are in many fishes, because of the rapidity of consummation until photographs were taken under nearly ideal conditions in nature (see Plates I-IV). The method used in securing the photographs was similar to that used by some ornithologists. A nest of common shiners was located at a spot where the water was shallow and clear. If the shiners were at a high pitch in their spawning activity they would return after a period ranging from one-half to several hours and carry on normally with the camera mounted on a tripod and operated by an observer only 4 to 5 feet away. By utilizing exposures of 1/100 of a second or less most action could be stopped and the spawning process pictured. This method will probably be helpful in studying the habits of other nest building species among our fresh water fishes.

MIGRATION.

An inshore migration in lakes and, at least in some localities, an upstream movement is made by the common shiner. At the south end of Cayuga Lake, near Ithaca, New York, large schools are found moving toward

shore during the first two weeks in May when the water has reached a temperature of 55° to 60° F. Their coming is eagerly awaited by bait dealers since, at this time, the common shiner is in demand as bait for the pike, *Esox lucius*. Nurnberger (1931, p. 215) has noted the presence of large schools of the common shiner appearing along the shore of Big Sandy Lake, Minnesota, on June 1, 1928, when the water temperature was 68° F. In the absence of actual reported observations of spawning in ponds and lakes it is assumed that the common shiner resorts to the gravel riffles of tributary streams, but Hubbs & Cooper (1936, p. 65) have pertinently stated that "its abundance in some of the inland lakes (Michigan) suggests that it may also spawn successfully over the gravel shoals of these lakes."

In streams there appears to be at least a slight upstream migration from the deeper pools where the adults have wintered. On May 8, 1939, adult common shiners were found moving upstream into the trap of a weir placed across Grout Brook, the inlet of Skaneateles Lake, Cortland County, New York. Constant surveillance of the waters below the weir had failed to note any shiners before this date. The nearest satisfactory wintering place was 300 or more yards away and it is not at all improbable that they wintered in the lake 600 yards distant. Just how far individual shiners may migrate is, in the absence of tagging experiments, unknown.

SEXUAL DIMORPHISM.

Sexual dimorphism is pronounced in the common shiner, as in most other nest building or territory guarding cyprinids, as *Semotilus*, *Campostoma* and *Nocomis*. Breeding males of the common shiner attain a larger size, have well developed pearl organs or breeding tubercles and are more highly colored than females. It is obvious that the largest females in a stream exceed in size the smallest breeding males (Text-figure 1). Nevertheless the difference in size is one of the best characters for distinguishing the sexes at a given nest and in many instances of spawning I have yet to see a male spawn with a larger female. It is difficult to generalize regarding the actual sex ratio but with adult shiners on the spawning ground invariably there are more females than males. The maximum size for male common shiners is about 8 inches in total length. A male *Notropis cornutus chryscephalus* in breeding color is figured in Forbes & Richardson (1920: opposite page 147) and a male *Notropis cornutus frontalis* in Greeley (1927: plate number 5).

The following color notes were made one hour after preservation in 10% formalin, from specimens of *Notropis cornutus cornutus* taken from over a nest in Salmon Creek at Ludlowville, New York, on June 6, 1939. The sides of the breeding males become suffused with red, the amount varying considerably with the individual. The posterior border of all fins tends to have a red band which in turn is edged by a much narrower clear area. There is a pronounced tendency for the pectoral and ventral fins to become suffused throughout with red except for a light posterior border and a milky white anterior border. The rays of the dorsal, caudal and pectoral fins tend to become dusky just anterior to the red band while the base of the anal fin usually remains milky white. The base of the ventral fins shows a slight tendency to become dark in some individuals. The branchiostegals are red and the lower part of the cheek and opercles are at times a dull red. The upper part of the opercles and cheek are a slate blue as well as a narrow band immediately behind the opercle. There is a longitudinal mid-dorsal streak and a streak on each side of the back which vary from a silver to a greenish color but at all times are highlights on a dark background which make excellent field recognition characters (see Plate II).

Breeding females are dusky above and silvery along the sides. In a few cases a slight amount of red has been seen, especially at the posterior border of the caudal and anal fins. The rays of the dorsal, pectoral and caudal fins

tend to become dusky while the ventral and anal fins are usually white. While females have a faint longitudinal streak down the mid-line of the back and one along each side of the back they are not as pronounced as in the males. The swollen abdominal region of the ripe or near ripe female is also a helpful field character.

The males begin to show color about a month before spawning, a subdued red tint appearing first on the lower fins. The red which is to be seen along the sides in the ripe males develops last and appears only a few days before spawning takes place. After breeding the color fades quickly and is usually gone in two weeks, the red on the sides being the first to go. However, an occasional male is taken even in late summer with a slight amount of color in the fins.

The breeding male has well developed pearl organs scattered on the back in front of the dorsal fin, on the nape, on the top of head and on the snout; a few under the anterior part of the eye, in the region of the premaxillaries and maxillaries and a single row along the lower jaw. The tubercles on the head are better developed than the more posterior ones. A few minute pearl organs occur on the upper sides, below and in front of the dorsal fin; on the posterior border of the opercle; on a few of the anterior scales just dorsad of the base of the pectoral and on the belly between the pectoral and ventral fins. An irregular row of fairly large pearl organs is to be seen on the anterior edge of the first ray of the dorsal fin and smaller ones occur on the sides of the first few dorsal rays. The dorsal side of the pectoral fins are well supplied with fairly large tubercles which undoubtedly are of use in enabling the male to hold the female in spawning. Minute tubercles occur on the ventral side of the pectoral and on both sides of the ventral fins near the anterior border. A careful examination of a dozen ripe females disclosed no tubercles. However, Fowler (1912, p. 473) reports that "occasionally a tuberculate female is found."

As with the color, the tubercles of the male grow gradually, starting about a month before spawning, and are usually gone within two weeks after spawning, although the scars of the larger pearl organs may often be seen up until one month after breeding.

FUNCTIONS OF BREEDING TUBERCLES.

The well developed breeding tubercles on the snout, chin, head and on the back, in front of the dorsal fin, of the males are of unquestionable value in the fighting which takes place in attempting to hold a territory and in driving away predators which attempt to eat the eggs. These tubercles are also a protection to the male in the sporadic digging activities in which they engage. Probably the only tubercles which are of value in the spawning act are those on the dorsal side of the pectoral fin which functions as a grasping organ and those on the ventral side between the pectoral and ventral fins which come in direct contact with the side of a female (Plate II).

TIME OF SPAWNING.

In Big Sandy Lake, Minnesota, Nurnberger (1931, p. 215) reports that spawning occurred in 1929 between June 24 and 29 when the water reached 66°-70° F. In Illinois, according to Forbes & Richardson (1920, p. 148) spawning occurs from May 1 to the last of June. Hubbs & Cooper (1936, p. 65) give the spawning season in Michigan as extending from the latter part of May into June and mention that "spawning probably rarely occurs at water temperatures lower than 60° to 65° F." In western Pennsylvania spawning takes place in May and June while in New York the season may extend from the last two weeks in May until the middle of July in some of the colder Adirondack streams. About Philadelphia, Pennsylvania, Fowler

(1909, p. 540) reports that the shiner spawns from late April to early summer. Tracy (1910, p. 68) gives spring and early summer as the season in Rhode Island. In the Connecticut Lakes in Maine Kendall & Goldsborough (1908, p. 31) give the breeding time as spring or early summer, depending on the temperature of the water.

The lowest water temperature at which I have actually observed shiners spawn is 64° F. but they very likely begin to spawn at a temperature of 60 F. or thereabouts. However, in certain cold streams spawning probably occurs at a slightly lower temperature. Spawning has personally been observed when the water temperature was as high as 78° F. and Greeley (1929, p. 172) saw *Notropis cornutus frontalis* spawning in Silver Creek, a tributary of Lake Erie, Chautauqua County, New York, as late as July 9 at a water temperature of 83° F. At any one locality spawning is usually over in ten days although ripe males are often seen for longer periods.

No breeding was observed taking place at night and at this time few adult fishes remain in close proximity to the nest. Most of them retire to the deeper pools nearby where they are relatively inactive. The spawning act was seen as early as 9 A.M. on May 27, 1939, in Willseyville Creek at Willseyville, Tioga County, New York. Spawning reached a high point about 12 noon and gradually tapered off after 4 P.M., none being noted later in the day than 6 P.M. Spawning had reached a peak of activity at this particular locality on May 27. Earlier and later in the season there was but little breeding activity at this place except in the afternoon.

SPAWNING SITE.

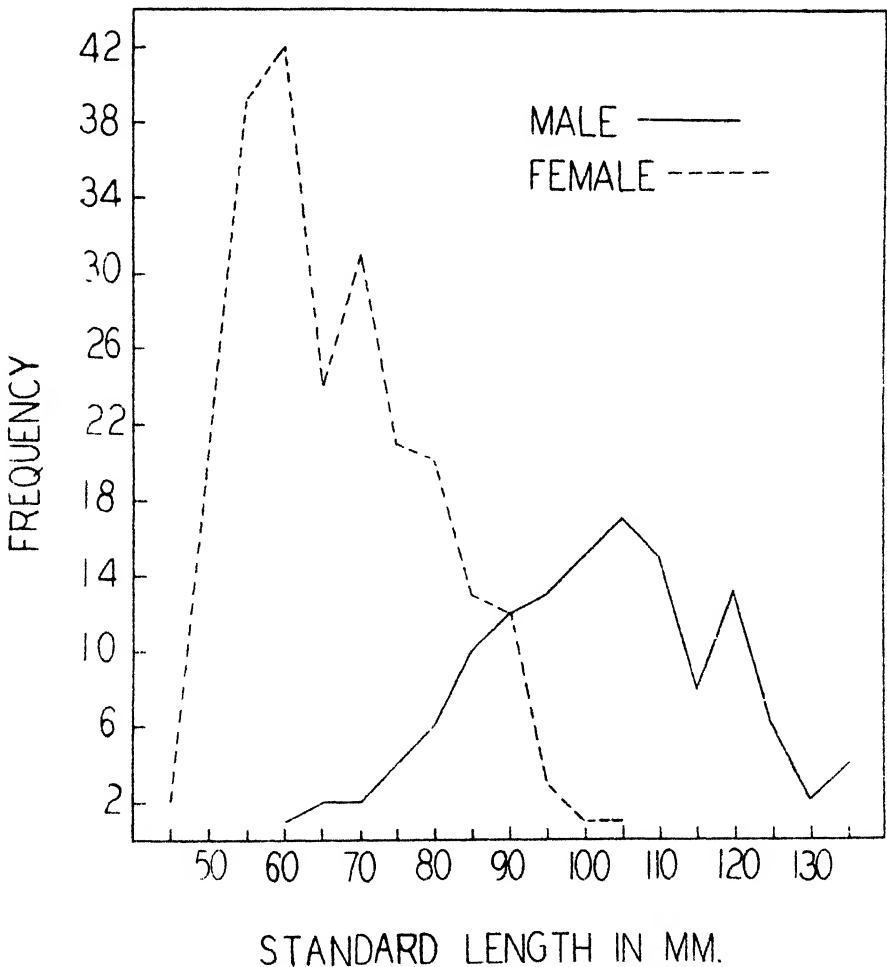
A very important factor in explaining the wide distribution and the local abundance of the common shiner is its capacity to spawn successfully in many different habitats. Shiners may (1) spawn over gravel beds in running water, (2) excavate small depressions in gravel or sand in running water or, (3) utilize the nests built by other species (Plate I), even when these nests occur in pools as is frequently the case with *Exoglossum*. They appear to prefer the nests of other species as nesting sites when they are available, although in 100 yards of Catatonk Creek, at Candor, New York, on May 31, 1939, shiners were observed utilizing all three of the above-mentioned nesting places. Their preference for *Exoglossum* nests, especially in small streams, often finds them spawning over these nests in the relatively quiet waters of shallow pools rather than using the gravel riffles which are so common nearby. The depth of the water over a spawning site is usually less than 8 inches except when nests of other fishes are used. Four large male shiners were once observed spawning over an *Exoglossum* nest situated at the edge of a deep pool in 2 feet of water.

GRAVEL BEDS AS A NESTING SITE.

Shiners often utilize gravel in or at the head of riffles as a spawning site. These areas can hardly be considered nests although they can easily be distinguished by the cleared nature of the bottom. The clearing away of the silt is accomplished in two ways; first, by the constant moving of the male fish over the gravel during which the lower fins make some contact with the bottom, and, second, by the occasional sporadic digging motions practiced by the male. He inserts his head between two pebbles and, by a quick sidewise motion, dislodges one or both of them. Only rarely do they pick up small stones in their mouths.

Fowler (1909, p. 540) has observed breeding schools of several hundred brilliantly colored males packed close together over clear gravel or sandy shallows in the region about Philadelphia, Pennsylvania. Several splendid opportunities have been had recently for observing spawning (subspecies *cornutus*) over gravel in Fall Creek, Ithaca, New York, and in Salmon Creek,

at Ludlowville, New York. In western Pennsylvania *Notropis cornutus chrysocephalus* has been observed spawning over gravel in riffles. Of the above-mentioned localities when gravel is utilized many more shiners spawn together over a given area than when the nests of other species are used. At Ludlowville on June 6, 1938, from 80 to 100 males (Text-figure 1) had taken a position in a riffle over a gravel bottom where the water varied in depth from three to five inches. Under such conditions each male attempts to hold a small territory which, of course, is quite limited because of the large number of males in such a restricted area and, at most, consists of a distance of three inches or so to either side. Much fighting occurs among the males but after one retreats from the rush of another male he usually comes back to his original position and the rushes may be repeated many times between spawnings. The offensive activity of a male consists in quickly



Text-figure 1.

Frequency distributions of breeding males and females of *Notropis cornutus cornutus* taken from over one spawning area in Salmon Creek, at Ludlowville, Tompkins County, New York, on June 6 and 9, 1939. Measurements of standard length were taken on 130 males and 232 females preserved in alcohol.

circling either to right or left and attempting to strike with the tubercled snout. Few direct hits are made as opposing males are usually alert and beat a quick retreat at the moment an antagonist starts circling. The water "boils" over such groups of males as they break water with their dorsal and caudal fins during this fighting and manoueuering for position. Occasionally "deferred combat" (Reighard, 1910, p. 1129) occurs as two males of nearly the same size (Plate III) tensely swim off parallel to each other, often for a distance of 3 to 5 feet. If they are of equal size they soon return to or close to their original position on the gravel. There was a tendency at times for this large breeding group to break into two, about half the males moving upstream several feet and there repeating the same combat for territory.

Approximately 150 females could be seen on the gravel below the holdings of the males. When they were ready to breed the females would come upstream and take a position over a male and spawning would take place in a manner to be described later. This large spawning group was somewhat unusual in that it was located in a shaded spot under a huge American elm tree and received no direct sun during the afternoon. In such a situation where spawning occurs over coarse gravel the eggs may be seen and recovered by picking up or scuffing the pebbles. Some of the eggs are free between pebbles, singly or in groups, while others are found adhering to the stones.

At times, especially toward the end of the spawning season, a large depression is made on the bottom by a large group of spawning males. Whether a nest-like excavation is apparent depends somewhat on the type of bottom. At Ludlowville the pebbles were fairly large, averaging about one inch in diameter with few under one-half inch in diameter. Under conditions such as this the digging activities of the males have little effect other than to give a clean look to the area. In lower Fall Creek, at Ithaca, New York, a similar breeding group will excavate a shallow depression in the bottom consisting of sand and small gravel, which is often 3 to 4 feet in diameter. Such nests are hardly distinguishable from the type which is discussed next.

NESTS EXCAVATED BY THE COMMON SHINER.

Both subspecies *cornutus* and *frontalis* have been observed digging and guarding their own circular nests, which are usually 8 to 12 inches in diameter. In most cases a pit partly or wholly excavated by *Semotilus* (Plate I) or *Campostoma* is taken over by a number of shiners, the number varying usually from 3 to 20 males although occasionally but one male occupies a nest. These nests are most often built at the head of a riffle but are also often seen in fairly fast flowing riffles. They are probably never built in quiet water. The males make the nests by digging activities in which they insert their heads between two stones and by jerking the head to the side dislodge the stones laterally. Several males will engage in this digging at one time although there are frequent interruptions as the males dash at each other, vieing for the position furthest upstream in the nest. This digging usually occurs irregularly between spawning acts.

UTILIZATION OF NESTS OF OTHER FISHES.

Several authors including Greeley (1929, p. 172), Hankinson (1920, p. 8, and 1932, p. 415), Hubbs & Cooper (1936, p. 65) and Van Duzer (1939, p. 73) have pointed out instances of the common shiner utilizing the nests of other species, such as *Nocomis micropogon*, *Nocomis biguttatus*, *Semotilus a. atromaculatus*, *Leucosomus corporalis*, *Exoglossum maxillingua* and *Campostoma anomalum*. Shiners appear to prefer the pebble nests of *Nocomis* and *Exoglossum* when available. Their second choice under most

conditions appears to be the pit and ridge nest dug by *Semotilus* and the author has observed them taking over and enlarging the circular pits excavated by male *Campestris anomalum pullum*. The breeding pattern is the same, however, whether the nest of another species is utilized or a nest of its own is excavated.

On several occasions *Semotilus* and *Nocomis* have been working on their nests at the same time that shiners were spawning there. The male shiners seldom attacked a male *Semotilus* and the *Semotilus* in turn continued removing stones from his pit and piling them in a ridge upstream (see Reighard, 1910, p. 1125). At times he would turn on and strike with his tuberculate head a shiner that became too bold. As Hankinson (1932, p. 418) has pointed out a male *Nocomis* will frequently continue bringing stones to add to his ever-growing nest even though many shiners are present and spawning is occurring. An amazing example of the complacency of a male *Nocomis micropogon* was noted in Catatonk Creek at Candor, New York, on May 31, 1939. Twenty male and thirty female *cornutus* were swarming over a *Nocomis* nest. These were accompanied by a dozen breeding *Notropis rubellus*. A number of specimens of *Eroglossum maxillingua* and *Rhinichthys cataractae* were darting in from their position on the periphery to eat what eggs they could secure. During this great activity which made the water "boil" over the nest, the male *Nocomis* calmly added stones to his nest for a period slightly more than one hour without at any time attacking any of the breeding fishes that were so close. At the same time the male shiners carefully respected the *Nocomis*. However, female *Semotilus* or *Nocomis* seldom appear when shiners swarm the nests, and actual spawning has not been seen under these conditions.

With spawning *Eroglossum*, as Van Duzer (1939, p. 73) has pointed out, "the mating of the cut-lips was always definitely lessened and sometimes stopped by their (*cornutus*) presence and activity at the nest." It is quite probable that the male *cornutus* have learned to respect the sizeable male *Semotilus* and *Nocomis*, armed as they are with well developed pearl organs on the head, while they have become equally familiar with the abortive rushes of the non-tuberculate and usually smaller male *Eroglossum*.

An interesting side light is the considerable number of natural hybrids which occur largely as a result of this habit of spawning over the nests of other species. Two species have often been seen spawning at the same time over a *Nocomis* nest

Hybrids of the combination *Notropis cornutus* × *Notropis rubellus* are frequently collected and both of these species have been seen spawning over a *Nocomis* nest at the same time (see Hankinson, 1932, p. 417). The hybrid *Notropis cornutus* × *Nocomis micropogon* has been recorded by Greeley (1938, p. 51). *Clinostomus elongatus* spawns over the nests of both *Notropis cornutus* and *Semotilus atromaculatus atromaculatus* and both Greene (1935, p. 89) and Greeley (1938, p. 51-52) have recorded the hybrids *Notropis cornutus* × *Clinostomus elongatus* and *Semotilus atromaculatus atromaculatus* × *Clinostomus elongatus*. Greeley (1938, p. 52) has also reported hybrids *Notropis cornutus* × *Semotilus atromaculatus atromaculatus* and *Notropis cornutus* × *Leucosomus corporalis* which likely result from *cornutus* spawning over the nests of these species. Thompson (1935, p. 492) has mentioned that in Illinois hybrids of *Notropis cornutus* are common presumably because *cornutus* spawns in the nests of other species.

SEX RECOGNITION.

The female that successfully spawns, invariably approaches the nest from the downstream side and assumes a position dorsad and slightly downstream from the male, who faces upstream (Plate I). Should she continue upstream to a position in front of a male, as occasionally happens, she would be driven away by the rush of a male, usually the male holding the dominant

position in the nest. The male would usually dart at and cause to retreat downstream any female getting into the nest at his body level, that is, near the bottom of the nest. In case a female was chased she would beat a retreat downstream, assume a position from one to several feet below the nest and then gradually come upstream again over a male. The constant turning of his head from side to side enables him to spot any fish which comes above him. The behavior of a male when a female has assumed a position above him is evidence that he recognizes her by the position she takes. The male at this time will, while facing upstream with body nearly straight, incline his body from side to side so that his reddish sides flash alternately (Plate I). While the male may react to the mere presence of a fish body above and behind him, there is a possibility that the male is attracted by the milky white area about the slightly protruding external opening of the oviduct of the female. In the case of one ripe female, but two inches long, this white area was so pronounced it might easily be seen by an observer standing five feet away. It must surely be an attractive mark when viewed from the position of the male. A female will take a position above any male who is in or slightly below the nest. Often a small male on the outside edge of the nest (Plate II) will be successful in spawning more often than the large male dominating the nest since the latter is forced to spend a large part of his time attempting to chase away other fishes. However, one exceptionally large and vigorous male was once seen holding a *Semotilus* pit so effectively by his wild dashes at intruding male *cornutus* that he successfully spawned with a half-dozen females in about one and one-half minutes before any other males seriously challenged and finally displaced him.

There is one bit of evidence that female *cornutus* react to fish of larger size whether of the same species or not. At one instance a male *Eroglossum* returned to his nest, and took a position facing upstream. He moved slightly to right and left over the nest much as does a male *cornutus*, and several female *cornutus* took a position above and dipped down to take a spawning position beside him. The male *Eroglossum* reacted by turning and rushing at them and finally chased the female shiners away from the nest.

SPAWNING ACT.

With a female above a male and the male alternately inclining himself to a semi-recumbent position first to one side then to the other, conditions are set for the spawning act (Plate I). The female dips downward beside that side of a male which is inclined toward the bottom or making the more acute angle. The anterior end of the head of the female is just beyond the anterior border of the pectoral fin of the male. The pectoral fin of the male is inserted under or slightly behind the head of the female, the distal end of his pectoral being curved upward around the female. At the same time his caudal peduncle is swung up over the caudal peduncle of the female and then the caudal peduncle of the male moves downward. As a result of this pressure the female is lying on her side at right angles to the male with her head toward shore and usually with her ventral side upstream (Plate II).

The male continues to bend his body in such a way as to enclose the female within a curve (Plate III). It appears that the eggs are laid at this moment, the eggs being forced out by the downward pressure exerted by the male. The female then straightens out (Plate IV) and shoots head upwards to, or almost to, the surface just as the male begins to straighten himself. When observing a large group of spawning shiners, females may constantly be seen breaking water as they come out of the spawning embrace. The speed with which this spawning act takes place is a fraction of a second or just slightly longer than the time necessary to snap ones fingers quickly, and the details are about impossible to see clearly with the unaided eye, even when observed at close range. The spawning act is much like that

of *Semotilus atromaculatus atromaculatus* as described by Reighard (1910, p. 1130).

The male shiner immediately takes his position facing upstream and may spawn again with another female in a few seconds. The female swims slowly downstream a few feet, takes a position below the nest and soon comes back to spawn again, at times with the same but usually with a different male. One female was observed to spawn twice with the same male in a period of one minute. A small male about three inches in total length who at the time was the lone male on the nest, was counted spawning 20 times within 10 minutes. There were about 30 females below and over this nest. Although a male will spawn with the female to either side, many more righthanded matings were noted. An exceptionally vigorous male may hold the dominant position in the nest, and spawn many times, for as long as 20 minutes. Most males, however, drop downstream and rest in less than half this time; thus the spawning individuals over a nest are changing constantly.

Male shiners recognize the spawning act when they observe another male spawn. When a breeding group has been purposely frightened away from a nest it is usually one of the smaller male shiners that returns to the nest first, drives away the egg predators and spawns with the first female to come upstream. On the completion of the spawning act from 5 to 10 males would immediately rush to the area and the never-ending battles for the leading places in the nest would resume.

One group of breeding shiners had become conditioned so that when a daily train rushed by at high speed only 20 yards away, spawning continued without interruption. A horned dace that was present in the nest at the same time, however, beat a hasty retreat toward the deep pool above. These shiners were easily frightened by any quick movement such as the passage of a bird close above the water or the movement over the surface of a ripple caused by a sudden gust of wind. However, they did not move when loud vocal notes were made within six feet of them.

A common water snake, *Natrix sipedon sipedon*, approximately two feet in length, once quietly moved downstream into a nest. The snake stopped with its head near the surface and its body dragging on the bottom six inches below. Neither the spawning shiners nor other fishes such as *Rhinichthys a. atratulus* and *Camptostoma anomalum pillum* appeared at all disturbed. Several shiners swam leisurely up and casually examined the intruder and one even investigated by touching the snake's body with its mouth as if testing its edibility.

An *Eroglossum* nest that was used by a spawning male shiner was completely covered by the author with large flat stones. The male shiner returned shortly and made a few dashes at adult *Rhinichthys atratulus* that were eating what eggs they could get in the crevices. The male shiner remained in the immediate vicinity for three minutes and then dropped downstream twenty feet and attempted to drive away another male shiner with a holding over an *Eroglossum* nest.

No exact observations are available but it is thought that but few eggs are laid at one time, probably not more than fifty. Occasionally a very ripe female will lose her entire supply of eggs when she is handled and it is thus probable that at times many more eggs are laid than at others. As has been mentioned above the eggs fall to the bottom and lodge on and among the pebbles of the nest. Apparently few are washed downstream. The flow of water over a depression such as *cornutus* may make, or over the pit of a *Semotilus* nest, is such that eddies are formed, bringing the water in the bottom of the pit to a relatively quiet condition even in fairly fast riffles. Thus very few eggs are washed downstream. When *Eroglossum* and *Nocomis* nests are made the eggs are usually driven into the anterior slope of the nest by the current.

Other species of fishes, chiefly darters and other minnows, are quick to dart in to eat the eggs after a spawning act is consummated. Indeed some *Rhinichthys atratulus atratulus* seem to be conditioned so that they make a mad dash to the spot at the moment spawning occurs. The male shiners are usually successful in keeping these predators at bay.

Although some species of fishes desist from taking food during spawning, both male and female *Notropis cornutus cornutus* will eat during this period. Ball (as reported by Marshall, 1939, p. 153) "found no cessation of feeding during the breeding season" in *Notropis cornutus chrysocephalus*. Ripe females lying in the middle layers of water just below the nest will readily rise to the surface to take insects which are floating by. Males, when not too much occupied with their territory guarding or spawning, will rise to eat these insects.

After the spawning period many of the larger males are found dead. Invariably they are badly fungused. However, most have probably reached the end of the normal life span of the species at this time. Numbers of dead specimens of other species of minnows such as *Campostoma* and *Nocomis* are often seen just after the spawning season is over.

EGGS AND YOUNG.

The demersal eggs become adhesive when water-hardened about two minutes after they are laid. At first they are orange but fade considerably in a short time. The average diameter is 1.5 mm. The eggs drop between and are washed under pebbles and some are subsequently buried by the digging activity of the males to a depth of several millimeters in the sand. Some single eggs are found and numbers up to twenty have also been found in loose clumps.

The incubation period is unknown, as every effort to hatch eggs in aquaria resulted in failure. Little definite data is available on the behavior of the newly hatched larvae, but later, after the loss of the yolk sac, the post-larvae may be seen in small schools at and slightly under the surface. At this time they often school with the young of other species as *Catostomus commersonnii commersonnii*, *Hybognathus regius* and *Notropis hudsonius hudsonius* in the sluggish waters about Ithaca, New York. In smaller streams in the same region the young *cornutus* are to be found in the company of the young of *Rhinichthys atratulus atratulus*, *Clinostomus elongatus* and *Catostomus commersonnii commersonnii* and other species. After they have reached a length of around 15 mm. they are still to be found in small schools but now they are often seen in fast water as well as in pools.

Throughout the summer the young of the year tend to refrain from associating with juveniles and adults of the same species although by September a few mixed collections of young and small adults have been taken. The schools of juveniles and adults, with but few exceptions, resort to the deeper pools during winter. However, the young are often to be found in great numbers, associated with the young of other species, in shallow, ice covered backwaters along streams. For a detailed description of the eggs and young of *Notropis cornutus chrysocephalus*, the reader is referred to Fish (1932, p. 339).

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SUMMARY.

1. In May an inshore migration in lakes and, in some cases at least, an upstream movement is made by *Notropis cornutus*.

2. Sexual dimorphism is pronounced. Breeding males have well devel-

oped pearl organs or breeding tubercles, are highly colored and reach a larger size than breeding females. The breeding tubercles on the various parts of the body are of value in the fighting which occurs among the males, in driving away predators and in the breeding act.

3. Spawning occurs from May 1 through the middle of July in the north-eastern states, beginning usually when the water has reached a temperature of 60° to 65° F. At any one locality spawning lasts about ten days and is limited to the daylight hours.

4. The common shiner may (1) spawn over gravel beds in running water, (2) excavate small depressions in gravel or sand in running water or, (3) utilize the nests built by other species such as *Nocomis micropogon*, *Nocomis biguttatus*, *Leucosomus corporalis*, *Semotilus atromaculatus atromaculatus*, *Eroglossum maxillingua* and *Camptostoma anomalum* whether these are built in running or the still waters of shallow pools. They prefer to spawn over the nests of other species when these are available.

5. Hybridization often occurs with *Notropis cornutus* as one parent largely as a result of their spawning over the nests of other fishes.

6. The number of males that will spawn over one nest varies considerably, there being from one hundred or more over a gravel bed to as few as one male over a small depression. More females are present at the nests than males.

7. Males fight continually for the leading position, the position furthest upstream in the nest.

8. A male shiner recognizes a female and takes a semi-recumbent position alternately from one side to the other when the female approaches from the downstream side of the nest and comes to a position above and slightly downstream from the male.

9. The female reacts to a fish whether it be a male common shiner or another species providing he has taken a position over a nest, head facing upstream and moving slightly from side to side.

10. The female takes the initiative in the breeding act by dipping downward, to lie beside the male. The male throws his caudal peduncle over that of the female, curves his body by bringing his head and tail in close proximity with his pectoral fin underneath the head of the female. The eggs are forced from the female at this moment while she lies, usually on her side, her ventral surface facing upstream and her head pointing toward shore. The entire breeding act is over in a fraction of a second and the details cannot be clearly seen with the unaided eye.

11. Probably fewer than fifty eggs are laid at once. The demersal eggs become adhesive after water-hardening in about two minutes after being laid and drop between the pebbles on the bottom of the nest to which they adhere. When first laid they are orange and average 1.5 mm. in diameter.

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EXPLANATION OF THE PLATES.

PLATE I.

A typical breeding group of *Notropis cornutus cornutus* over a nest begun by a male *Semotilus atromaculatus atromaculatus* at Willseyville, New York. The large male at the right, occupying the leading position in the nest, is assuming a semi-recumbent position in anticipation of spawning with the small female now dipping toward his left side. He is followed by eight males which are easily recognized by the prominent light colored streak along the upper side. Three small females are to be seen to the left and one is downstream from this group of eight males. Another female appears above the third from the last male in the nest. Several other females, that do not appear in the photograph, were scattered further downstream. All fishes are facing upstream.

PLATE II.

The beginning of a spawning act in which a small male *cornutus*, to the right of the larger leading male in the nest, has thrown his body over that of the female who now lies on her side. The breeding male is just starting to bring his caudal peduncle toward the head in the typical breeding curve. The right pectoral fin of the male is under the anterior end of the female. This much of the spawning act had happened so rapidly that the other three males to his left have apparently not noted it. The upstream male will probably turn on the spawning male and drive him off when he finally sees him. The open mouth is typical of a spawning male. Two female *cornutus* are to the left and one is behind the male on the left side of the spawning group. Two males on the downstream side of the nest appear at the extreme left of the figure. Note the adult *Rhinichthys atratulus atratulus* in the right foreground on the periphery of the nest in a search for eggs.

PLATE III.

The climax of the breeding act has been reached with the male *cornutus* in the foreground curved over the female. Although the pectoral fin of the male is usually under the female it is above in this case and the position of the female is somewhat abnormal. The eggs are forced out of the female at this point. Another female may be seen above and to the left of the leading male in the nest. The two males near the center of the figure are in a position males assume before attempting to dash at each other. Note that their heads and caudal fins are apart while their bodies almost touch in the middle. The light colored tubercles of the males stand out against the dark background of the skin. Three males may be seen at the extreme left of the figure where the water breaks over the riffle. An adult *Rhinichthys atratulus atratulus* is present in the right foreground.

PLATE IV.

The breeding act has been completed. The male *cornutus* is straightening his body and the female has started to move upward. The large dominating male to his right is turning to rush at the male that has just spawned. Three other males are near the middle of the nest and four more appear at the left of the figure. One small female is present just in back of the largest male near the center of the photograph. Two other females appear in the upper right hand corner. An adult *Rhinichthys atratulus atratulus* is present in the foreground.



THE BREEDING BEHAVIOR OF THE COMMON SHINER, NOTROPIS CORNUITUS (MITCHILL)



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THE BREEDING BEHAVIOR OF THE COMMON SHINER *NOTROPIS CORNUTUS* (MITCHILL)

2.

Divergence and Probability in Taxonomy.

ISAAC GINSBURG

U. S. Bureau of Fisheries, Washington, D. C.

Taxonomists of past generations have generally been content with describing and establishing species based on one or but a very few specimens. The business of distinguishing species by this method is a comparatively easy matter. Using very few specimens as a basis of comparison, closely related species, in their large majority, appear to be sharply differentiated. In occasional instances a sharp distinction on the basis of even a few specimens proved troublesome, and such specimens were generally assumed to represent "varieties," "races," etc., of the same species.

This easy method proved to be inadequate, as it was bound to. Later investigators found that such distinctions all too frequently did not accord with their material. This is due to the fact that related species often approach closely or even intergrade in their differentiating characters. From a taxonomic point of view we do not know all we should about a species until we know its range and manner of variability, at least in the few crucial characters by which it is distinguished from closely related ones. This is, of course, true of races and other subdivisions of the species. Taxonomists come more and more to realize this and act accordingly. In dealing with mass data obtained in the study of variability, it is desirable to reduce them, when it is consistent to do so, to single figures, statistical constants, for convenience in comparison, discussion and interpretation. This paper considers one such class of constants, that concerned with the measure of divergence, which is of the utmost importance to taxonomists, as related to another class, that concerned with the expression of probability, which is often used in place of the first.

Probability in its numerical expression is often referred to as the "test of significance." As it is my hope that this paper will prove to be of interest to taxonomists to whom the latter term is not a household phrase, it may be well to consider briefly here its precise meaning.

When a taxonomist compares the likenesses of and the differences between two closely related populations—be they species, subspecies, races, etc.—he does not study the variability of the entire population, but his comparison is based on a relatively restricted number of specimens; in other words, on two samples drawn one each from the two populations. The degree of difference or divergence shown by the two samples determines his conclusion regarding the taxonomic rank of the two populations, whether they are to be considered as species or as belonging to a category of the next or second next lower rank. However, we know that different samples drawn even from the same variable population will generally not be the same, but, on the contrary, due solely to chance, will exhibit differences of greater or lesser degree. The question then comes up, is the difference shown by the two samples compared in taxonomic research a real population difference, or is it due to the fortuities of sampling? It may be assumed that due solely to chance it may happen sometimes that two

samples drawn even from the same population will exhibit a difference as great or greater than that between the two samples of the two populations compared, and in that case it would, of course, be inappropriate to separate the two samples taxonomically. An answer to the above question, in part, as discussed below, is given by certain mathematical formulae developed in connection with the theory of probability. By the use of such formulae—based on the difference between the averages of the two samples, the squares of the deviations of the individual specimens from the averages, and the number of specimens in the samples—it may be determined, for any one given character, how often such a difference, or a greater difference, is likely to be obtained at random, by mere chance, from two samples of the same population. If such an eventuality is likely to occur but rarely, say, two times or less per 100 trials, we may state that the difference is “significant” and that it may be concluded with comparative assurance that the two samples compared in our taxonomic research belong to two distinct populations.

The above is a bare outline of the “test of significance,” but it is hoped that it presents its essential idea. The “test of significance” then results in a number that represents the numerical expression of probability, indicating the probable value of a difference determined in biologic research, or the probable reliability of the two samples compared, for the purpose of drawing pertinent conclusions. In the practical application of the formulae an arbitrary limit is postulated and a figure obtained as a result of the test of significance, which equals or is higher than the accepted limit, is taken to denote “significance.” It should be noted in particular that this test merely establishes that a determined difference is “significant.” It does not indicate definitely whether the difference is of specific, subspecific or racial magnitude. The taxonomic rank of the two populations compared is determinable definitely only by some appropriate measure of divergence.

It is very important and can not be too strongly emphasized that it is necessary to draw a sharp distinction of the fundamental difference between the two concepts, measure of divergence and expression of probability, from both a theoretical and a practical standpoint. This fundamental idea has been formulated by Fisher (1936, p. 59) as follows: “It must be stressed that the test of significance calculates a probability; it does not calculate a racial difference.” Although it is, or should be, generally realized that a test of probability is not the same as a measure of divergence, yet, somehow, the two concepts become inextricably mixed in deliberation and discussion. Somehow or other there appears to be a lingering idea with some biologists that the greater the numerical value of the figures showing “significance” obtained by the use of current formulae that express probability, the greater the divergence between the pair of populations compared. Often this is true; but it is only a partial truth, and like all partial truths it is bound to lead us sadly astray. This confusion of concepts appears to be a stumbling block not only with biologists who are not given much to the employment of statistical formulae, but even with some who employ them extensively.

If two separate comparisons be made of two pairs of populations, and the test of significance have a much greater numerical value as between one pair of populations than between the other, it does not always mean that the former pair diverges to a greater extent; although in many cases a greater numerical value for the test of significance does coincide with a greater degree of divergence. The real meaning is that for the comparison showing a greater numerical value, one or both samples are too large for our purpose, for that particular pair of populations with their spread and relative regularity of the frequency distributions and their difference between the means. Smaller samples would have been sufficient to prove what we set out to discover, if our purpose was the determination of the probable mathematical significance of the difference between the means. More specifically, when

two values of significance obtained in two comparisons are above its accepted limit, but differ widely—say, one is 10, the other 50—the meaning is that the samples in the latter comparison are larger than necessary for the purpose of determining significance. It is evident, therefore, that figures of different magnitudes which express mathematical probability or significance, cannot consistently be employed for the purpose of expressing relative divergence.

A notable example of a substitution of such constants is furnished by the "coefficient of racial likeness" which is extensively used by some physical anthropologists as a measure of population divergence. Regarding its proper use Morant (1923, pp. 205-207) states as follows:

"It [the coefficient of racial likeness] is not a true measure of absolute divergence, and must not for a moment be considered as such, but nevertheless we shall speak of it, for convenience, as if it were an absolute measure of racial affinity. When it is said that a low coefficient between two races A and B indicates a closer relationship than a higher coefficient between, say, A and C, what is meant always is that it is more probable that A and B are random samples from the same population than that A and C are."

This is a lucid statement of the underlying idea. The coefficient of racial likeness is essentially an expression of probability and not a measure of divergence. Only as an expedient make-shift is it used as a measure of divergence. It has been extensively used as such by Morant and others. However, a make-shift should be used only when it does not lead to false conclusions; but the coefficient of racial likeness often does lead to absurdly inaccurate biological conclusions, as shown by Seltzer (1937). It would seem to be best to abandon altogether the use of this coefficient as a measure of divergence, and if it is still desired to employ it as an expression of probability, to change its misleading designation. (The coefficient of racial likeness is used primarily to combine two or more characters for the purpose of measuring divergence. For any single character the misleading results obtained by using as a measure of divergence a certain formula that fundamentally expresses probability, is discussed by me in another place (1938, pp. 279-282). The problem of measuring divergence for a multiplicity of characters I have considered in another paper (1939).)

Physical anthropologists of the school of the London Biometric Laboratory having become inured to the use of the coefficient of racial likeness—which, as stated, is essentially an expression of probability—as a measure of racial divergence, we find a similar substitution of constants employed in still another connection. In a later paper, Morant (1936, p. 32) states as follows: "Different characters will arrange the series in very different orders, and it is not clear, at first, why more importance should be attached to one of these orders than to any other . . . A grading of the characters in order of importance for the purpose in view can be obtained by noting the number of significant differences found for each in a particular set of comparisons." He then lists the percentage of times, of the total number of comparisons made, in which each one of a number of characters showed a "significant" value for α (alpha is the chief, compound factor in the formula for determining the coefficient of racial likeness; Morant postulates that if α is greater than 10, it shows significance).

Now, what do we understand by an "important" character? Obviously a character is important in distinguishing populations when it manifests a comparatively high degree of divergence, and the opposite is true of an unimportant character. With respect to populations of specific or lower rank, the degree of divergence it shows is the criterion by which the importance of a character may be judged. The importance of characters in such populations may be considered from two points of view.

First, often a character may be said to be important in the sense that it may be employed to divide a number of related populations of similar taxonomic rank, such as a number of races within a species or a number

of species within a genus, into two major groups. Its importance then constitutes a group divergence. Such a character will show a comparatively high divergence when a population of one group is compared with a population of the other group, and a relatively low divergence when a pair of populations within either group is compared, although even within the limits of each group it will generally show different degrees of divergence to a certain extent. In such species or genera, when the populations are divided into pairs in all possible combinations and the pairs compared, the character, in general, will appear important in approximately half the number of comparisons and unimportant in the remainder; providing the number of populations in one group approaches equality to that of the other group, as they often do.

Second, more generally, the terms "important" and "unimportant" as applied to any given character is applicable only in connection with a given pair of populations, and they have no universal application. A character that may be important, that is, manifest a comparatively high degree of divergence, with respect to one pair of populations may be unimportant with respect to another pair, and *vice versa*. This is often true of a series of closely related populations. In a species containing many races, or in a genus comprising many species, that are divisible by important group characters into primary, secondary and tertiary groups, certain other important characters may crop up independently in some of the groups, and the same important character may appear in groups that are otherwise not immediately related. Often important characters thus appear in such kaleidoscopic fashion that they cannot be used consistently for the major division of the species in a genus or the races in a species. In general, therefore, a character may be said to be important only with respect to the comparison of a particular pair of populations.

Morant's attempt to determine certain characters as of general importance is, therefore, rather irrelevant. However, this is beside the point. What I am after is to point out that here also Morant uses a test of probability to express what is fundamentally a divergence.

In comparative biological research, the essential thing we are after, in general, is to determine a difference or a divergence. This is true of both morphological and physiological comparisons, using the latter term in a broad sense to comprise all life processes including the complicated chain of events connected with the reproductive process. Whether we compare the morphology of pairs of related populations in taxonomic work, the comparative yield of milk for a given breed of cattle in feeding experiments, the perceptible effects of a particular drug on guinea pigs or human beings in pharmacological research as compared with controls, etc., we are trying to determine the precise divergence between two variable quantities or populations (in cases similar to the latter, between treated and untreated individuals, or between the same individuals before and after treatment). This is our prime object. A secondary consideration is the mathematical determination of the probable reliability of the samples from a study of which the data are drawn that form the basis of our conclusions.

This being so, it is remarkable that hitherto most attention has been directed to the secondary consideration, the determination of probability, while the primary object, the determination of an adequate measure of divergence, has been rather neglected. A measure of divergence that is universally employed is the difference between the means of the two sets of data compared, but this is evidently not always adequate. It is certainly altogether inadequate in taxonomic research. A fundamental defect of measures of divergence in taxonomic research based on such values as the mean, median, or mode, is that they represent denominate numbers which are altogether unlike, their absolute values differing widely, in pairs of populations that differ by widely unlike characters. Consequently, the figures expressing the measures of divergence for different pairs of populations,

when based on denominate numbers, are not fairly comparable. That the figures are not comparable for characters the measures of which are expressed in different units is self evident; but even when expressed in the same unit they are often not fairly comparable, if the characters are unlike. For instance, if the divergence of a pair of closely related populations of mice be expressed by the difference of the means of the tail length measurements, and that of a pair of populations of fishes by the same difference of the head length measurements in the same unit, the relative divergence of the two pairs may not be fairly comparable. Furthermore, measures of divergence based even on the same character expressed in the same unit, are not fairly comparable for different pairs of populations if the spread of their distributions differ widely. An ideal measure of divergence, one that could be used as a universal yardstick, should be an abstract number based on the degree of overlap, positive or negative, of the two frequency distributions, such as the measure employed by me (1938). That measure appears to be fairly adequate for taxonomic work. Whether that measure, or a modification of it, will be found applicable to research problems similar to the other two mentioned above, I am not prepared to discuss. I am here speaking chiefly from the point of view of the taxonomist. (In another paper considering the measure of divergence with respect to a multiplicity of characters, I (1939) concluded that a measure of divergence based on the principal character is fairly adequate, and that if the other characters are to be considered at all in its determination, they are to be afforded minor weights. In any further attempt at the combination of several characters, the figures for the different characters used should be such abstract numbers that measure the divergence of every one separately, rather than denominate numbers that express their absolute values.)

Current formulae that are generally suitable for the determination of the probable reliability of samples investigated in taxonomic research, have as their fundamental bases the difference between the means of the two samples and their probable or standard errors, the size of the samples, and their variability as expressed by the standard deviation. The practical use of this determination in taxonomic research is rather limited. Fisher (1936, p. 59) states succinctly the proper, general application of the determination of significance as follows:

"It will be seen that the test of significance does no more, and attempts no more, than to answer the straightforward question, 'Could these samples have been drawn at random from the same population?' It calculates a probability. If the probability is very small the answer is 'No.' If it is not so small as to reach the level of significance required, the answer is 'Yes, they could.' The answer never is 'Yes, they must have been.'"

To this I may add that in taxonomic practice, in the majority of cases, the actual arithmetical determination is rather unnecessary. If the two frequency distributions are fairly regular (that is, the frequencies in the successive classes diminish successively at both sides of the mode, even though the distribution be skewed) as they usually are when based, respectively, on homogenous material and the sampling is adequate; and further, if the modes are at different even though closely adjacent classes, as they usually are when the two populations represented by the distribution really differ and the degree of divergence is rather considerable, the arithmetical determination of probability will usually result in a "significant" figure. Most of the cases covered by Fisher's first contingency may then be judged for practical purposes by a mere inspection of the data arranged in the form of frequency distributions.

In regard to pairs of distributions falling under Fisher's second contingency, that is, distributions showing a divergence of relatively low magnitude, and the differences of which do not reach the level of mathematical significance as determined by the samples examined; this class of examples will no doubt include many in which the differences are biologically signifi-

cant. In nature, differences in taxonomic characters between pairs of populations form a gradual series from small to large values, with virtually all possible intermediate values. (The series may be visualized as represented by a straight line of the equation, $mx - y = 0$.) Small values near the extreme of the series must have a biological significance, although mathematically their significance appears doubtful. For such populations the arithmetical determination of probability is of no practical value by itself, because it fails to give a definite answer to the question in which we are interested, namely, is the difference real, even though small, or is it due to the vicissitudes of sampling? The mathematical answer to this question, to adapt Fisher's style in the preceding citation, virtually is "no" or "yes," which is no direct answer at all. When the test for significance results in a low numerical value, lower than the accepted limit, it may mean either one of two things: (1) The difference is not real. (2) The difference is real but its magnitude is such that the samples are not large enough to prove its reality mathematically. Larger samples are necessary for a mathematical test of significance. The meaning of too low a figure then may be similar but opposite to what was noted above that too high a figure for significance shows that the samples are too large; but when the figure expressing significance is high the answer is direct and positive, and when it is too low the answer is indirect and limited.

While some of the small but real differences that are not too extreme will show mathematical significance when the size of the samples are greatly increased—and theoretically any real difference, no matter how small, will show significance by taking samples that become infinite as the differences, in a series of pairs of populations compared, approach zero—in actual practice the size of the samples necessarily must be more or less limited. In workaday biological practice, therefore, it can hardly be doubted that small differences of biological significance will appear mathematically insignificant. In passing, it may be mentioned that instances may occur in which it would be impossible to obtain very large samples. Supposing we compare two populations of which the actual number of living individuals is very limited, and find a small difference which, based on the entire number of living individuals, does not show any mathematical significance. That does not mean that such a small difference does not have a biological significance. In general, in cases coming under Fisher's second contingency, our conclusions must be based on the biological evidence rather than on mathematical deduction.

From the standpoint of the comparative practical unimportance of the determination of probability in taxonomic research, it has received an undue share of attention from certain biologists whose work is essentially taxonomic, such as those investigations dealing with population or "racial" differences in various groups of living things. In general, this is also true of some statistical constants now in use in taxonomic work as noted below. From the point of view of the taxonomist at least, a great deal of what is being done along this line may be said to represent mathematical, rather than biologic research, employing biological data for the purpose of solving mathematical problems or formulating mathematical propositions. Of course, mathematics represents one of the important disciplines in the sum total of human culture, and there can be no objection for workers who are interested in mathematical research to illustrate their problems and propositions by the use of biological data, if they wish to do so. But it should be remembered that a great part of such research is of little importance in solving taxonomic problems. In taxonomic problems, what we are greatly interested in is to determine divergence as precisely as possible, while the determination of probability is of secondary importance. The thing to be regretted is not so much that a great deal of attention is being paid the latter, but that it is apparently done at the expense of the former. A few examples of published reports will illustrate this idea.

An outstanding, valuable and well known taxonomic work to which reference is often made in biological discussions is that by Crampton (1916, 1925, 1932) dealing with the terrestrial gastropods of the genus *Partula*. The investigation forming the basis of Crampton's reports is unusual as compared with taxonomic studies in general, by the number of specimens examined and the detail with which they were examined. The information furnished by Crampton makes it evident that *Partula* is at the present time level in an early and active stage of speciation, and as such, its detailed study is of special importance for an understanding of the process of evolution.

The study of speciation or racion in *Partula* does not lend itself altogether readily to statistical treatment, because some of the important distinguishing characters are rather of a qualitative nature and are not readily expressible in terms of definite figures, although it is not altogether impossible to do so. One important character, the direction of the spiral of the shell, dextral or sinistral, can be expressed in terms of exact figures. In some species it is always either sinistral or dextral; while in other species, or populations of lesser rank, the direction of the spiral varies with the individual. In the latter, Crampton very helpfully gives the precise numbers or proportion of the sinistral and dextral individuals in his samples. For certain other characters that are measurable with more or less precision, Crampton furnishes a wealth of statistical data and constants in tabular form.

However, the tables published by Crampton furnish only a part of the information that his data were in position to furnish, and that not the most important part. For each character he generally gives the range of variation, the mean, the standard deviation and the error of the last two figures. For some species he also gives their coefficient of variation. Now, in the distinction of the species, or the different populations within a given species, and in the interpretation of the relationship of the various populations, of specific or lower rank, of what material difference, in general, is a knowledge that the standard deviation, or the coefficient of variation, in one is larger than in another population? Also, at their best such data are only approximate, and of what material difference, in general, is a knowledge of the small value of the error of the mean for the foregoing purposes? These figures are interesting, but they are largely of academic interest. Of course, there can be no objection if an author wishes to furnish such figures. What is regretable is that more pertinent information is omitted. From a taxonomic point of view we are intensely interested in how far or to what degree the different populations diverge with respect to the various characters. For that purpose we are presented only with the ranges and the means of the various characters, and these are altogether inadequate. To determine the precise extent of divergence, by some such method employed by me (1938), frequency distributions for the different characters for the separate populations are needed and these are omitted for the characters based on measurements.

For three characters Crampton does give frequency distributions, namely, the direction of the spiral of the shell, the degree of tooth development, and the color pattern. Crampton's presentation of the data for the last two characters is especially interesting, because they are rather qualitative in their nature. As such, their determination in terms of definite figures is only approximate and dependent to some extent on a subjective estimate. Qualitative characters are generally described by authors in adjectival words or phrases that necessarily must be indefinite to a certain extent, and not in terms of definite figures. Crampton shows that such characters also can be expressed, approximately, in the form of frequency distributions. Similarly qualitative characters in other groups as well may be expressed in figures, and although such figures necessarily must be only approximate at their best, they should yet prove to be of importance in

determining divergence between closely related populations. An interesting example of this kind is furnished also by the work of Sumner on mice of the genus *Peromyscus*. Characters based on color differences, in general, are qualitative, yet Sumner (1929) has found it possible to express quantitatively seven such characters, presenting his results for two of them in the form of histograms (p. 111), and giving the averages for the other five.

I have used Crampton's reports as an example because they constitute a work of unusual value and interest as compared with the ordinary run of taxonomic papers, but the foregoing statements apply to many other published papers in which taxonomists employ statistical methods. I may here cite three recent papers in my own specialty, in fishes, that happened to come to my attention, namely, by Schultz (1937), by Matsubara (1938) and by Storey (1938). These papers are much less extensive in scope than Crampton's reports, in that they deal with much fewer populations. They also differ more or less in the manner of the statistical presentation of the data; but they illustrate in different ways some of the points raised above.

Schultz compares the Pacific with the Atlantic population of the capelin. He compares a larger number of characters than usual in such cases, but for each character he publishes only the range of variation and the mean with its error. These figures are altogether inadequate for determining the precise divergence between the two populations, the thing in which Schultz as well as other taxonomists are chiefly interested. Had Schultz's data been published in the form of frequency distributions, they would constitute a valuable example showing the differing degrees of intergradation of the several characters in two closely related populations that differ by more than one character, in addition to forming a basis for the determination of the precise divergence between the two populations. (Schultz's method of combining several characters for the purpose of determining divergence I consider in another paper (1939).)

Matsubara, working with Japanese lizardfishes, does not employ statistical formulae or constants and does not calculate probabilities. Nevertheless, his method is essentially statistical in its nature, as it properly should be in a problem such as the author was confronted with. However, the data for the variability of the characters that are employed in comparing and distinguishing his populations (which happen to be of specific rank), are presented in graphic form and are not altogether suitable for the purpose of calculating the extent of divergence in terms of precise figures. Of course, the frequency distributions of the several characters may be approximately determined from the graphs, but it is very difficult or impossible to get the exact figures. For the precise determination of divergence, it is important to have the actual frequency distributions obtained during the investigation.

Storey, reporting on an investigation of the Atlantic populations of *Harengula*, also presents her data in graphic form and the same remarks apply to hers as well as to Matsubara's method of presentation. Furthermore, her data for characters having a continuous variation, namely, proportional measurements, are presented in the form of curves "smoothed by threes three times." "Smoothing" has the slight advantage of producing somewhat more regular curves which are rather more pleasing to the eye, but it has an important disadvantage in that the curves tend to mask heterogeneity in the material studied. That the material of *Harengula pensacolae*, for instance, possibly was heterogeneous is shown by her comparison (p. 35) of the specimens from Sanibel with those from other localities. Storey suggests that the differences in the measurements may be due to the different preservative used, formaldehyde instead of alcohol. This may be so to a certain extent, but part of the differences quite possibly represent a population divergence. The difference in the gill raker count of the Sanibel specimens would certainly seem to represent a population divergence. However, in clupeid species in general, the gill raker count differs greatly with the

size of the specimens and Storey does not appear to have segregated her data in sufficiently restricted size groups to reveal any possible intraspecific population differences in this character.

Detailed studies of other clupeid species have shown that they tend to diversification into distinct, statistically measureable, local populations of lesser rank, subspecies or races. It is highly probable that this is also true of the four Atlantic species distinguished by Storey. In view of the close approach or even general intergradation between these four species in the characters determined, it is quite possible that if such a detailed study be made, the relationship of the various populations will receive a modified interpretation than that obtained by the data available to the author. The size of the samples studied by the author were rather restricted (Storey, 1938, pp. 16-17), and in order to apply to them current statistical formulae, the grouping of the data adopted necessarily had to be comprehensive. A study of larger samples and of the same characters determined by the author, measurements, gill raker count and ventral scute count, with the data segregated by locality, and those of the measurements and gill raker count by smaller size groups, would possibly present a somewhat different picture of the relationship of the various populations, than that obtained by the grouping of the data as adopted by the author. It is evident that not only is it important—in order to determine precise divergence, distinguish properly the different populations and determine their relationship—to have frequency distribution tables published, but to subdivide the data where necessary by size, sometimes also by sex, and also by locality where heterogeneity is suspected.

Instead of presenting detailed frequency distribution tables, Storey gives derivatives of her data (table 3, pp. 16-17) in the form of certain constants, the most important of which are: the standard deviation, the mean, the difference between the means of the two populations compared and its standard error. These are not of much value in determining divergence as stated above. She also gives the relative deviate and the value of p , which express probabilities, as they are intended by the author to do, but are not suitable to determine divergence.

A paper based on the study of populations of flies that are of much interest in connection with some phases of the species problem, was very recently published by Mather & Dobzhansky (1939). It deals with the two well known "races" of *Drosophila pseudoobscura*, generally designated in the literature, following Lancefield's suggestion in his original report (1929) announcing their distinction, as race A and race B. The two populations occupy different but overlapping geographic ranges; they are also incompletely segregated ecologically (Dobzhansky 1937a, pp. 406-408).

The apparent principal character proving that the two populations are distinct is a physiological one and refers to the sterility of hybrid offspring when they are crossed. The sterility is partial, being confined to the males. Hybrid females are fertile, at least in part. A backcross of F_1 females to males of either parent population gives rise to both sterile and fertile males. Besides this principal character, Mather & Dobzhansky review and enumerate other, minor diverging physiological characters, and differences based on gene arrangement in the chromosomes.

Morphological differences between the two populations that have so far been discovered show certain degrees of intergradation. The object of the paper mentioned is to deal with the morphological characters, and it takes up five such characters, namely, the number of teeth in both the proximal and distal sex comb on the leg of the male, the length and width of the wing and the length of the tibia. The former two are sex characters. The latter three characters were determined for males and females separately and they were found to differ by sex as well as by population. All five characters differed also according to minor populations or "strains" within each one of the two major populations.

Now, this problem is fundamentally taxonomic in its nature. Our concern is the determination of the relative rank of the taxonomic category in which the populations are to be placed. This determination, in its turn, must have as its basis a determination of the relative divergence of the populations. Given the known facts regarding the populations, let us consider this particular case from the taxonomist's viewpoint. This case may not be as remarkable as it appears. Every careful taxonomist of wide experience no doubt can cite similar instances in which distinct populations show relatively low and varying degrees of divergence with respect to morphological differences. Its apparent remarkableness rests on the partial sterility of the hybrid offspring correlated with a relatively low morphological divergence, and very likely is due to the fact that relative sterility and fertility of hybrids has been definitely determined only in a rather negligible number of very closely related populations.

In appraising the case under consideration taxonomically, it is well to consider the relative importance of physiological and morphological criteria in classification. There is no fundamental reason why the former should not be used for this purpose the same as the latter. Morphological criteria are generally used in taxonomy because they are determinable more readily and with greater precision. In the relatively few known cases in which a physiological character shows a greater divergence than any known morphological character, the former may be employed as the principal character in determining the taxonomic rank of the pair of populations compared.

In the case considered, the sterility criterion is evidently important, and we may confine ourselves to a consideration of this physiological criterion. The precise value of this criterion in classification in general cannot be said to be as yet firmly established, and it cannot well be appraised, because it is known for relatively few populations as compared with their untold multitude. However, in general, it is evident that this criterion is not absolute, but, on the contrary, it is fully expressible in terms of degrees of magnitude only. Even in regard to the classical example of hybrid sterility, the mule, one now and then finds in the literature apparently authentic records of fertile individuals. Possibly, if sterility in the mule be investigated extensively and systematically, the percentage of fertile individuals may be found to be greater than such haphazard observations would seem to indicate. At any rate, judged by what we already know in regard to hybrid sterility in general, it is evident that this criterion shows all degrees of differences, from perfect or almost perfect sterility through different degrees of partial sterility to comparatively unhampered fertility, depending on the populations crossed.

There is an incomplete correlation between relative sterility and the relative degree of divergence of morphological characters. When an attempt is made to cross two closely related populations that have reached a sufficiently high degree of divergence, as determined by morphological criteria, to be generally regarded as species, one of several things may happen: (1) They may not be crossable. (2) They may produce zygotes showing various degrees of inviability, that is, they die at various stages of development, depending on the populations. (3) When viable offspring are produced, they may be sterile or show infertility of varying and rather pronounced degrees. On the other hand, when a cross is made between two populations the divergence of which is of such a rather low degree, as determined by morphological criteria, that they are generally regarded as of a taxonomic rank below that of species, fertile offspring generally seem to be produced. However, even with our present rather meager knowledge regarding sterility of hybrid offspring, it is evident that there are frequent exceptions to the above generalizations. A pair of closely related populations, which, judged by morphological criteria, are generally regarded as species sometimes, perhaps often, on being crossed give rise to a progeny that is fertile.

Since the magnitude of sterility is relative, being merely a matter of degree, it follows that if it be used as a criterion for grading populations into taxonomic categories, it would be necessary to draw arbitrary lines between the species and various categories of lower rank, the same as when morphological characters, especially quantitative ones, are used for that purpose. It is then necessary to devise a measure for expressing the degrees of sterility, and the most obvious measure that suggests itself is the relative percentage of sterile and fertile individuals in the hybrid progeny of the pair of populations compared. For instance, we may decide arbitrarily that if a pair of closely related populations on being crossed produce, on the average, a progeny 90% or more of the individuals of which are sterile, the populations are to be designated as species; they are to be designated as subspecies when the percentage of sterile individuals is 75 — 85%, other things being equal; they are to be designated as races when the same percentage is 60 — 70. These are the tentative arbitrary lines which I (1938) suggested to draw for morphological characters. For the sterility criterion even less data are extant than for morphological criteria, to enable us to draw the most pertinent arbitrary lines; but wherever drawn the lines evidently must be arbitrary. It may perhaps be found desirable to draw arbitrary lines for the sterility criterion that differ in numerical value from those employed for morphological criteria.

There being no absolute correlation between morphological divergence and relative sterility, the sterility criterion, if employed in taxonomy, evidently is to be used on a par with morphological criteria and coordinate with them. Whichever is the most divergent, it is to be used as the principal character for determining the taxonomic rank of the pair of populations compared. If any morphological character shows a divergence of specific magnitude the two populations are to be designated as species even though a cross between them produces offspring that are 100% fertile. Conversely, if the degree of sterility is greater than any morphological character that has been discovered, the former is the chief factor to be used in determining the taxonomic rank of the pair of populations compared.

Bearing the preceding propositions in mind, let us turn to the question of the taxonomic rank of the two major populations of *Drosophila pseudoobscura*. It is evident that for a pertinent decision of the question we need to know the degree of divergence of the various characters, morphological as well as physiological. For this purpose the paper by Mather & Dobzhansky furnishes only the averages of the morphological characters, which are entirely inadequate for measuring divergence, as discussed above. From a taxonomist's viewpoint, the data presented educe further questions. The authors very properly subdivide each one of the two major populations, races A and B, into minor populations which they designate as "strains." In the morphological characters the differences between the extreme strains within each race is nearly as great or greater than the differences between the major, composite populations. The question then is, when is a population to be designated as a "strain" and when is it to be designated as a "race"? More specifically, from the data presented it is evident that we have two (or more) "strains," one in each "race," that morphologically are approximately alike. What criterion then do they use for placing one strain in one race, and the other, morphologically similar strain, in the other race? Although I searched the paper for a definite statement in answer to this question, it could not be found. Apparently their basic criterion is sterility, for Dobzhansky (1937b, p. 285) states: "... the F₁ hybrid males from crosses between race A and race B are always sterile ..." But other questions present themselves: On how extensive a body of data is the above quoted statement based? Especially, on how many crosses between different strains is it based? Is sterility of F₁ hybrid males absolute also between strains that are alike morphologically?, since we have seen that there is a rough correlation between morphological divergence and sterility. I did not deem it

necessary for the present purpose to enter into a complete analysis and review of the recorded investigations that have a bearing on an answer, if any, to the preceding questions. Even should sterility of the hybrid male eventually prove not to be absolute between all the strains, it nevertheless seems evident from the above quoted statement that its degree, in general, is comparatively high.

Let us see now to what taxonomic conclusion we may come on the basis of the data that have been recorded.

A consideration of the condensed data presented by Mather & Dobzhansky makes it apparent that the morphological character showing the greatest divergence between the two major populations, taken in their entirety, refers to the number of teeth in the proximal sex comb of the male (with that based on the number in the distal comb a close second). While the precise degree of divergence between the two primary populations cannot be determined from the condensed data, it seems apparent that divergence is rather considerable but intergradation must also be pronounced. Arranging the averages in the authors' table 2 in their order of magnitude, five of the extreme minor populations, "strains," of race B have averages of 5.88, 5.92, 5.96, 6.00 and 6.08 respectively, nearly the same as three extreme minor populations of race A with averages of 5.92, 5.96, and 6.00. The total number of minor populations compared are 20 of race B and 19 of race A; those having the averages nearly alike are, consequently, 25% of the total "strains" of B and 16% of A, or an average of about 20%. Had the authors given their data in the form of frequency distributions, the individuals comprised in the samples enumerated would apparently be seen to represent intergrades to a large extent. In addition, it seems apparent that a considerable number of individuals of the other minor populations, especially of those populations the averages of which are next in magnitude of those enumerated above, would also prove to be intergrades. It may be reasonably expected then that the two major populations taken in their entirety would show an intergradation of 25% or more in the morphological character of greatest divergence, according to the measure of divergence suggested by me (1938). According to the suggested arbitrary lines in the foregoing paper, this represents a divergence of racial or nearly subspecific magnitude. Judged by this criterion, on the basis of the incomplete data, the two populations perhaps are to be taxonomically designated as races, or they may possibly be near the borderline between the subspecies and the race.

The other important matter to consider is sterility. As stated, for the present it is difficult to form a judgment regarding the precise treatment of this criterion in taxonomy in general. We must also bear in mind the fact that in this particular case sterility is confined to one sex, the male. While by the use of morphological criteria species are sometimes based on characters of one sex, and properly so, the question remains whether the same course is to be followed with respect to the sterility criterion. Nevertheless, the fact of hybrid male sterility appears to be of tremendous biological significance, especially if we assume that it is 100%, or nearly so, as the above quotation from Dobzhansky would seem to indicate. Therefore, taking into consideration the sterility criterion, the rather considerable divergence in two morphological characters, and the other differences mentioned by Mather & Dobzhansky, the divergence would seem to be approximately of subspecific magnitude. A taxonomist's best and most reasonable judgment based on the extant incomplete evidence, would then seem to dictate the course, at least tentatively, of recognizing the two major populations as subspecies. According to a common taxonomic practice, it may be desirable to formally distinguish them by name, as, for instance, to designate them *Drosophila pseudoobscura*₂ and *Drosophila lancefeldi*₂, employing the notation for subspecies as suggested in my (1938) paper.

The course here suggested will give taxonomic expression to the relative divergence of some of the major populations of the genus *Drosophila* with

respect to morphological criteria and the sterility criterion. Some of the other major populations diverge in varying but pronounced degree morphologically, and when crossed produce inviable or altogether sterile offspring; they are, therefore, recognized as species. The two populations under consideration diverge morphologically in lesser degree and produce partly fertile offspring, and are consequently designated as subspecies.

The sterility criterion may be broadened to include the various graded results that occur when a cross is made between two populations. The grades are: incrossability, inviability of zygotes graded, in its turn, according to stage of development at which they die, offspring viable but sterile (even such populations may be only partly crossable), progeny partly fertile. It is interesting to note that in the one genus *Drosophila* there appears to be a correlation, at least partial, between hybridization results and morphology. Species that are readily separable morphologically appear to be either not crossable or to produce inviable zygotes. *D. melanogaster* and *D. simulans*, a cross of which results in viable but sterile offspring (Sturtevant 1929), also diverge morphologically in a lesser degree than some other species, so much so that they were not distinguished until comparatively recently (see Sturtevant, 1921, pp. 91-92). Finally, the two major populations of *D. pseudoobscura*₁ show a comparatively low morphological divergence correlated with partial fertility of hybrids.

The differences between *D. miranda* and *D. pseudoobscura*₁ (Dobzhansky, 1935) seem to be rather intermediate between that of the latter two pairs of populations mentioned. They produce viable but altogether sterile offspring the same as the cross between *D. simulans* and *D. melanogaster*. But morphologically the difference between them is evidently not greater than that between "races" A and B of *pseudoobscura*, whereas *D. simulans* and *D. melanogaster* are more greatly divergent morphologically, showing one apparently discontinuous difference, that relating to the structure of the male genitalia (compare Sturtevant, 1921, especially his figures 13-14, p. 34, with Dobzhansky, 1935).

Dobzhansky (1935) and Dobzhansky & Tan (1937) describe important differences in the chromosome structure between *D. miranda* and *D. pseudoobscura*; but, except in the peculiar distribution and number of sex chromosomes, such differences are evidently also nothing more than a matter of degree, since similar differences appear to exist not only between the two major populations of *pseudoobscura*, but also between the "strains" or minor populations (see Dobzhansky, 1937b, pp. 92-95). In general, hardly the surface has been scratched in elucidation of differences in chromosome structure between very closely related populations, and it cannot be used at present as a criterion in classification with any degree of assurance.

D. azteca and *D. athabascæ* evidently constitute another example of two closely related populations of *Drosophila*, "... that are very similar externally but that produce sterile F₁ hybrids..." (Dobzhansky, 1937b, p. 113).

At least some of the major populations of the genus *Drosophila* have evidently reached at the present time level a fairly advanced stage of speciation, so that they are rather easily separable and are designated as species. Yet, even in this genus, when all major populations are considered, there is a certain gradual transition in degrees of divergence as determined by both morphological criteria, and physiological criteria based on hybridization. As for the minor, intraspecific populations, it may well be expected that various degrees of divergence will be discovered when the several species are subjected to such taxonomic analysis as was carried out by Mather & Dobzhansky on *D. pseudoobscura*₁. The same state of affairs very likely will be found to exist when we know more about the variability of some of the numerous poorly known species, or what are now recognized as species.

The taxonomic course suggested above indicates how a taxonomist would or should form a judgment in this particular case. A decision could be made with greater assurance, had the authors presented frequency distributions of at least the morphological character showing the greatest divergence. That would have given us a basis for a determination of the precise degrees of divergence between the minor populations and of the divergence of the two major populations by combining the data of each one of the two groups of minor populations, by some such method as was suggested by me (1938). Instead, the authors present only derivatives of their data in the form of means and squares of deviations for each character, and for a combination of characters, "a score," the latter by a method developed by Fisher. The main results of these figures is that they lead to other, final derivative figures expressing mathematical tests of significance of the differences between averages by standard methods. Now, just what are the values of the final figures in taxonomy? Do they convey any special meaning or ideas to the biologist, which would help him to come to a better decision, one made with greater assurance, in regard to the taxonomic status of the two populations, than that based on their morphological divergence and on the sterility criterion? The test of significance is interesting, but it is only of minor interest in taxonomy. In this instance especially, the definite determination of mathematical significance would seem to be of no more than academic interest. Arranging the averages given by the authors in their tables 2 and 4 in order of magnitude, one with some experience in applying current statistical formulae may see at a glance, without going through the actual arithmetical calculation, that the figures for the averages would result in values for the test of significance that would reach its accepted limits for the principal character. Any difference in the magnitude of the values beyond that limit does not have any special taxonomic meaning, as noted above. To an experienced and careful taxonomist, the figures for the averages, even condensed summaries though they are, speak much more eloquently, they constitute a much better basis for the formation of constructive decisions than the figures resulting from the test of significance. In sum, what the paper virtually accomplishes is to determine the figures for the test of significance. But this is only a secondary part of the problem. The main thing that we need to determine is the precise degree of divergence. This question is very inadequately answered.

While the greater part of the paper deals with the test of significance which is a matter of but minor interest in taxonomy, the subject of our primary concern, the determination of precise divergence to serve as a basis for forming a decision with assurance is incidentally considered, only insofar as the given averages form a very inadequate measure for such a determination. The valuable data determined by the authors in their investigation is not presented in such manner that the precise degree of divergence could be determined. Here then is an example of an investigation that bears the earmarks of care and reliability in its execution and carried out by reputable investigators, but the report of which fails to furnish the data in such form as will be of most help in deciding the question of our chief concern. To use a favorite expression of biological statisticians, the authors failed to extract all the information which their data were capable of furnishing, and the most important part is omitted. They fail to give even the ranges of variability of the different characters. This investigation is especially interesting in that, in a sense, it represents a study in experimental taxonomy. The groups of individuals, designated by the authors as "strains," upon which the data were determined, were bred in the laboratory from parents of known origin. It would be very interesting to compare divergence in such populations with that of the same populations as they occur wild; but the data as presented permit only an inadequate comparison.

I wish to emphasize here that I am not criticizing the paper as such. What I am after is to discuss its value in taxonomy, and the problem with which the paper deals is primarily a taxonomic one.

Physical anthropologists have been very assiduous in determining series of measurements of their material in many characters, as may be gathered by going through the volumes of *Biometrika*, for instance. Now, although they apparently have different standards than other systematists by which they determine the taxonomic rank of the populations studied by them, physical anthropology is nothing more than a highly specialized branch of taxonomy, dealing chiefly with one genus, *Homo*, and the same methods are applicable to this specialized branch as to taxonomy in general. In going through the published reports on physical anthropology in *Biometrika*, one finds that, omitting correlation studies, the figures on which the discussions and conclusions are based generally consist of the mean, the standard deviation, the coefficient of racial likeness, and their errors; sometimes the coefficient of variation is presented. However, what we are chiefly interested in, is the precise divergence between the populations, and those figures are not of much value in determining that, as stated.

The published reports that are used to illustrate the foregoing discussion, represent taxonomic investigations carried out by the use of appropriate modern methods, statistical methods. No fault can be found with the methods of investigation adopted by the authors. These are the methods that are to be recommended in taxonomic research. One or another of the investigations reported may be incomplete in one or another direction, but the methods adopted are correct as far as they go. Nevertheless they fail to determine the thing that is most important taxonomically, namely, the precise degree of divergence. This is generally true of published reports of taxonomic investigations in which modern statistical methods are employed. It seems that, in general, workers labor under the spell of statistical formulae developed through generations, and having to do chiefly with the theory of probability, something which is generally of but secondary importance in taxonomy.

What is to be especially regretted is that the class of reports under consideration, with frequent fortunate exceptions, omit the necessary data, complete frequency distribution tables, by which precise divergence could be determined by anybody who is interested. In general, in any investigation it is the data determined that are of primary importance. The manner of treatment of the data, their interpretation and the conclusions drawn from them, as given by the investigator, may not be the only possible ones. It is possible that some biologist at a later date, considering the subject from another point of view, may wish to treat the data in a different manner, and such treatment may even necessitate a different interpretation and lead to different conclusions. However, this would be impossible unless frequency distribution tables of the original data are presented. As it is, valuable data forming the quintessence of any investigation, representing a great deal of time and patient and concentrated effort, is thus practically lost to future workers. For instance, I (1938) employed a certain measure for determining precise divergence. This measure seems adequate in taxonomic work. However, some future worker may propose a measure that is more adequate, better expressive of the essential facts. But as most reports are presented now, it is not possible to determine divergence by the method employed by me, and will probably prove to be indeterminable by any future method that may be proposed. For the method mentioned at least, frequency distribution tables of the data are necessary, and this will likely prove to be so in any case.

In this connection a few words may not be amiss in regard to the economic aspect of the subject, having the editor's point of view in mind. Authors are sometimes confronted with the editor's desire to abbreviate manuscript reports by eliminating parts that appear not very essential. (It is unfortunate that this happens even with reports of outstanding merit.) In such cases, if elimination of some parts becomes necessary, and the question comes up whether to eliminate frequency distribution tables or graphic

representations of such tables, it is best to dispense with the latter. For, graphic representations merely constitute a device to "catch the eye" and clinch the author's conclusions, and it is usually possible to represent data graphically in more than one way, while the data on which the report is based are quintessential, as stated. If absolutely necessary, frequency distributions should be included even at the expense of parts of the discussion. In some cases, a report may be abbreviated even without urging from the editor, and yet be more informative than in the form in which it finally appears. For instance, some reports include tables giving detailed measurements of individual specimens, and yet they fail to include frequency distribution tables. But in mass data individual measurements are not of much consequence. (They may be of some interest in the case of very extreme or palpably aberrant specimens.) Such tables are rather superfluous and not likely to be carefully perused even by specialists directly concerned. In mass data what we are chiefly interested in, and what our conclusions are likely to be based on, is the frequency distribution of a population with respect to a given character under consideration.

It is fortunate for the cause of science that taxonomists are more and more abandoning the idea that taxonomy consists chiefly of the publication of local lists and catalogs, and descriptions of new species. This was all right for taxonomy in its pioneering stages, and if carefully and skillfully done, such papers still serve a useful purpose. However, gradually it is coming to be realized that the backbone of taxonomy is to be found in the careful and adequate comparison of related populations, whether they be of specific, subspecific or racial rank, by statistical methods, for the purpose of determining the intrapopulational variability, and interpopulational, their precise degree of intergradation, or divergence, with each other. This forms a proper basis for an understanding of the relationship of groups of closely related populations. Our chief interest is to determine the precise divergence between pairs of closely related populations, or concomitantly their precise intergradation, these two values being complementary. The determination of probability is of but secondary importance in taxonomy, although most attention has hitherto been given to it. In issuing reports of taxonomic investigations in which statistical methods are employed, it is essential to include frequency distribution tables of the data, so that precise divergence, or intergradation, may be determined, by existing methods or by methods that may be discovered in the future.

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3.

Miscellaneous Notes on the Eggs and Young of Reptiles.

ROGER CONANT & ALEXANDER DOWNS, JR.

Philadelphia Zoological Garden.

Everyone who is in close daily contact with an extensive collection of living reptiles soon accumulates an assortment of notes, which, while interesting in themselves, fail to fit the pattern of his contemplated papers. Thus we have assembled miscellaneous data on some 38 clutches of eggs and broods of young which, except as noted, were laid or hatched in the reptile house in the Philadelphia Zoological Garden. These data, while fragmentary in spots, we append below with the hope that like Klauber's (1938) "odd items of general interest," they may prove of use. At least we are fortified by the thought that with startlingly few exceptions the life histories of most reptiles are so poorly known that even scraps of information about them are welcome additions to herpetological knowledge.

The data available in the literature on this subject have come chiefly from captive specimens. The chances of observing egg-laying or hatching in the field are slight, and far more can be learned by maintaining gravid females in captivity under conditions as closely approximating natural ones as possible. Professional curators have contributed much information but here is a big field for the amateur herpetologist to make useful observations. All he needs is an ability to record data accurately, an inexpensive meter stick, and a friendly corner druggist who does not mind having his scales used in the interests of science.

Our weights and measurements were recorded as soon after laying or hatching as was convenient—usually on the same or the following day. Eggs were incubated in aquaria or glass jars nearly filled with moist, decayed wood. A flat piece of glass placed on top of each vessel served as a lid and permitted control of the moisture content within each one. When the under-surface of the glass "sweated" appreciably the lid was moved slightly to one side to allow evaporation. Conversely, when the hatching media became too dry it was sprinkled with water and the lid was replaced. Ordinary room temperatures prevailed during the incubation periods.

The weights and measurements of all female specimens were recorded after their eggs were laid. All weights are recorded in grams and all measurements in millimeters.

The letters "H" and "L" indicate the highest and lowest numbers, respectively, in each column of figures, thus representing the extremes of variation in each group. Unusually abnormal specimens are excepted. In cases where the highest and lowest figures appear more than once, only the first is designated by a letter.

For help in taking weights and measurements and in securing other data we are indebted to Mark Mooney, Jr., and to Edmond Malnate, successive superintendents of the reptile collection in the Philadelphia Zoological Garden. Several members of the Junior Zoological Society of Philadelphia also have given valuable assistance.

Alligator mississippiensis (Daudin).

A number of alligators, apparently recently hatched, were discovered along the swampy margins of a large pool on St. Simon's Island, Georgia, about August 20, 1937, by Robert S. Ingersoll, Jr. There were about 36 specimens in the group, but not all of them were captured. Measurements and weights were recorded when the alligators arrived at the Philadelphia Zoological Garden a few days later.

No.	Length	Weight	No.	Length	Weight
1	241	53.2	11	243	46.5
2	233	50.9	12	244	52.6
3	249	51.9	13	251	52.5
4	252	56.4—H	14	247	51.7
5	231—L.	42.9	15	257—H	52.6
6	247	53.2	16	247	52.5
7	247	47.0	17	244	51.2
8	249	53.2	18	236	42.7—L.
9	237	48.7	19	232	47.6
10	241	43.0			
			Average	243.58	50.02

Basiliscus vittatus (Gray).

Eggs found scattered about on the floor of the cage on June 29, 1937; all separate from one another. Shells buff, ovoid and rather soft. Female and male in captivity since March 20, 1935. Both were confined in same cage but eggs were infertile. The shell of egg No. 10 was badly dented.

No.	Length	Width	Weight
1	18.7—H	10.9	1.40
2	17.7	11.1	1.31
3	18.3	11.7	1.60—H
4	17.4	12.6—H	1.50
5	18.3	10.5	1.25
6	16.9	10.8	1.40
7	17.0	10.4	1.09
8	16.2	11.3	1.05
9	17.8	10.5	1.25
10	15.0	10.1	.65
11	15.6—L.	11.5	1.10
12	16.2	10.0—L.	.91
13	16.4	12.0	1.10
14	15.9	11.1	.90—L.
Average	16.96	11.04	1.18

Sceloporus undulatus fasciatus (Green).

Group of eggs brought to the Philadelphia Zoo about August 1, 1938. Donor could not furnish the locality where they were found, but stated it was in southern New Jersey.

No.	Total Length	Length (snout to vent)	Weight
1	45—L	22—L	0.4
2	46	22	0.4
3	49—H	23—H	0.3
4	45	22	0.3
Average	46.25	22.25	0.35

Egg No. 1 hatched on August 8, the others on August 11.

Ophisaurus apodus (Pallas).

Eggs found on July 20, 1937, in a cage occupied by several large, adult specimens received on June 9, 1937, from the Zoological Society of London. Probably the two eggs did not constitute the entire complement from any one female, but no others were laid.

No.	Length	Width	Weight
1	33.4	18.7	6.45
2	33.2	18.4	6.00
Average	33.3	18.55	6.23

Farancia abacura abacura (Holbrook).

A large female of this subspecies was found about August 20, 1937, coiled around her eggs under a large log on St. Simon's Island, Georgia, by Robert S. Ingersoll, Jr. There were approximately 15 or 20 eggs but unfortunately some of them were destroyed in transit to Philadelphia and the exact number could not be determined. Two of the eggs were hatched on October 9, 1937.

No.	Length	Weight
1	204	4.8
2	231	6.2
Average	217.5	5.5

Specimen No. 1 was deformed, its tail being kinked in an S-shape.

Ophiodryx aestivus (Linnaeus).

A female specimen collected at Royal Oak, Talbot County, Maryland, on July 2, 1938, was kept alive at Treasure Island Boy Scout Camp, where it deposited 9 eggs on July 13. The eggs subsequently were given to the Philadelphia Zoological Garden, where they began hatching on September 9, 1938.

No.	Length	Weight
1	183	1.3
2	201—H	1.4 H
3	190	1.2
4	182	1.1 I
5	191	1.3
6	180—L	1.4
7	192	1.3
8	187	1.2
9	190	1.2
Average	188.4	1.27

When the eggs first were discovered to be hatching one snake had completely escaped from the shell, another had its head half-way out of the egg and a third had the tip of its nose exposed. Six young had escaped by the morning of September 10; the numbers of slits made by these snakes in their respective egg shells were 5, 3, 2, 2, 2 and 1. All the young were very timid, drawing their heads back into the shells when an observer approached, or hiding in the hatching media after they had left the eggs. The last snakes escaped from their eggs on September 11. On this date the eyes of all were overcast, preparatory to shedding. The young were uniformly greenish-gray in coloration at first, but changed to uniform light green upon shedding their skins.

Coluber constrictor constrictor Linnaeus.

A clutch of eggs of this species was found buried in the earth by H. Leschke at Haddonfield, N. J., on June 19, 1936. They were stained brown, and salt-like protuberances on the shells made them rough to the touch.

No.	Length	Width	Weight
1	28.0	22.4	8.1
2	26.8	22.9	7.8
3	32.3	20.4 - 1.	7.4
4	31.0	22.0	8.3
5	29.8	22.1	8.0
6	27.3	23.2	7.8
7	27.5	21.7	7.1 - 1.
8	29.5	21.9	8.3
9	27.0	23.7 - H	8.3
10	29.5	21.0	7.8
11	29.0	22.4	8.1
12	28.2	21.8	7.3
13	29.7	20.8	7.9
14	31.0	21.7	8.4
15	27.7	22.8	7.2
16	28.5	22.4	7.7
17	33.7 - H	21.4	8.5
18	29.8	20.5	7.3
19	31.9	22.0	8.7 - F
20	30.0	21.5	7.6
Average	29.41	21.98	7.88

Twelve of these eggs hatched between August 7 and August 12, 1936.

No.	Length	Weight
1	278	5.2
2	288	5.2
3	275	6.1
4	272	4.6
5	279	5.8
6	282	6.0
7	266	4.5 - 1.
8	253 - 1	4.5
9	265	5.0
10	305	6.2 - H
11	294	5.6
12	284	5.8
Average	277.5	5.38

A group of 15 eggs of the same species was laid on June 6, 1938, in a cage containing several females, all caught a short time before near Philadelphia. Determination of which adult laid the eggs was impossible, but it was presumed that the entire lot was deposited by one female. All the eggs were white, the shells had salt-like protuberances on them and all except No. 11 were approximately the same size.

No.	Length	Width	Weight
1	35.6	18.2	7.5
2	36.3	18.6	8.0
3	32.1	20.0—H	7.9
4	33.7	19.4	7.7
5	36.7	19.2	7.8
6	33.6	19.6	8.3
7	34.1	19.8	7.8
8	37.6	18.4	7.3—L.
9	31.7—L.	19.4	7.5
10	34.9	18.6	8.0
11	46.5—H	17.4—L.	8.3
12	35.0	19.4	8.1
13	35.5	19.7	8.6—H
14	37.4	18.9	7.9
15	33.6	19.5	—
Average	35.62	19.07	7.9 (of 14)

Eggs No. 14 and No. 15 each had one end prolonged into a tip, and No. 15 was broken and leaking when found.

Four of the above eggs hatched in August, 1938, three on the 13th and the fourth on the 15th.

No.	Length	Weight
1	309	6.3
2	294—L	5.95—L.
3	336—H	6.8—H
4	303	6.4
Average	310.5	6.36

Elaphe obsoleta obsoleta (Say).

A female, probably from near Philadelphia, deposited 11 eggs in captivity on July 24, 1937. Five of these were separate but the others were adherent in pairs. Very probably the snake was disturbed during ovoposition; several specimens of other species were confined in the same cage with it.

No.	Length	Width	Weight
1	50.8	20.2	13.7
2	55.5—H	19.7	14.95
3	43.8	22.4	12.23
4	48.0	18.2	10.15
5	44.9	17.4—L	9.15
6	47.2 ¹	21.7 ¹	27.8
7	46.3\	23.7\—H	
8	47.7\	22.5\	26.7
9	45.5\	22.3\	
10	45.6\	22.5\	25.8
11	43.5\—L.	22.6\	
Average	47.16	21.2	12.77

Egg No. 4 had a marked constriction around its middle.

¹ Eggs which were adherent to each other. The measurements of eggs in such condition are grouped by brackets and their combined weights are expressed by one number, a policy followed throughout the text.

Two of the above eggs hatched on October 9, 1937.

No.	Length	Weight
1	361	10.3
2	360	11.2
Average	360.5	10.75

Elaphe vulpina (Baird & Girard).

Three large females collected by Robert H. Mattlin in May, 1938, at Little Cedar Point, Lucas County, Ohio, all deposited eggs during July, 1938. In two instances, many of the eggs were adherent, making it impossible to measure them and necessitating the weighing of them in groups as indicated in the tables below. In only one case was it possible to determine which female laid which eggs. Her weight and length are recorded in their proper place.

I. Eggs laid on July 20, 1938.

No.	Length	Width	Weight
1	43	24	161.7
2	43	25	
3	39	25	
4	42	25	
5	42	—	
6	43	—	
7	39	—	
8	46	24	
9	40	—	
10	41	24	
11	42	24	13.8
12	36—I.	24	
13	44	24	
14	47—H	27	
Average	41.93	24.6 (of 10)	14.75

II. Eggs laid on July 21, 1938. Length of female, 1229 mm.; weight, 409.5 g.

No.	Length	Width	Weight
1	47.3	25.7	18.9
2	47.0	24.1	17.3
3	48.2	24.0	18.7
4	50.4	24.5	18.5
5	48.0	25.8—H	19.3
6	42.9	23.7	14.8
7	38.1—I.	22.3—L	84.8
8	48.9	24.0	
9	51.2	24.1	
10	44.8	24.2	
11	58.5—H	23.3	
Average	47.75	24.15	17.48

Five of the eggs in this group hatched in September—three on the 1st and two on the 5th.

No.	Length	Weight
1	306	14.4
2	334—H	15.4—H
3	333	14.0
4	300—I.	11.9—I.
5	331	14.3
Average	320.8	14.0

III. Eggs laid on July 23, 1938. All were separate, probably because the female moved about while depositing them. The moist substance with which they were covered when laid was sufficiently adhesive to make pebbles from the cage floor stick to several of the eggs.

No.	Length	Width	Weight
1	39.9	26.9	16.65
2	40.7	24.5	14.4
3	40.7	26.1	15.4
4	37.8	27.3—H	16.2
5	44.4	23.5	14.4
6	29.1—L	25.0	14.7
7	45.0	22.9—L	15.0
8	47.2—H	25.0	16.5
9	41.8	24.4	14.8
10	40.4	24.4	14.3
11	40.6	24.6	14.9
12	38.4	24.3	14.1
13	42.9	27.3	18.5
14	45.7	26.9	19.8—H
15	42.8	24.3	14.5
16	39.9	26.1	15.8
17	43.1	27.2	13.9
18	41.9	26.3	18.1
19	35.7	25.5	13.6
20	38.1	24.6	13.4—L
21	38.6	26.3	15.1
Average	40.7	25.38	15.43

Pituophis melanoleucus melanoleucus (Daudin).

Two females from undetermined localities in southern New Jersey laid eggs in July, 1938. Many of the eggs in each group were adherent to one another, preventing complete measurements and separate weighings.

I. Eggs laid on July 12, 1938. Length of female, 1514 mm.; weight, 952.3 g.

No.	Length	Width	Weight
1	53|	34|	285.85
2	49|	35|	
3	—|	33|	
4	48|	35|	
5	49|	34|	
6	53|	—|	32.3
7	—|	34|	
8	61|	32|	
9	49	33	
Average	51.71 (of 7)	33.75 (of 8)	35.35

Two of the above eggs hatched on September 19, 1938.

No.	Length	Weight
1	412	35.8
2	376	26.8
Average	394.0	31.3

II. Eggs laid on July 13, 1938.

No.	Length	Width	Weight
1	57	33	155.0
2	—	32	
3	58	33	
4	59	34—11	
5	60	32	76.4
6	57	33	
7	66	31—L	39.9
Average	59.5 (of 6)	32.57	38.76

The eggs in this group started to hatch on September 18, and the last of the 7 emerged on the 20th. There were as many as 5 and 6 slits in some of the eggs and in one or two of them 2 or more slits crossed, to form loose flaps.

No.	Length	Weight
1	433	36.5—H
2	452—H	36.5
3	416—L	34.5—1
4	433	35.4
5	416	35.0
6	429	35.0
7	437	36.1
Average	430.86	35.57

The young snakes might be described as follows:

Ground color (above) yellowish-cream, becoming orange or brownish-cream on the sides. Dorsal blotches very dark brown (almost black), the most anterior dorsal ones enclosing two rather small, light areas. The orange or brownish coloration on the sides is caused by the anterior parts of the scales being of these colors. Some scales also have a longitudinal streak of the same colors on them.

Top of head olive-gray, marked with a few dark spots. A dark line across in front of the eyes, situated on the anterior edges of the frontal and supraoculars and the posterior edges of the prefrontals. A short, dark dash, obliquely downward from the back of the eye; another straight down from the eye. Some of the sutures between the upper labials dark. Belly whitish, washed with orange-pink.

Lampropeltis getulus floridana Blanchard.

Female collected 20 miles west of Miami, Florida, and sent to the Philadelphia Zoological Garden through the courtesy of Dr. Thomas Barbour. Eggs were deposited on May 19, 1936. Length of female, 1047 mm.; weight, 282.2 g.

No.	Length	Width	Weight
1	47.7	22.0—L	13.4
2	50.0—H	22.6	13.8—H
3	36.8	23.8—H	11.2
4	38.9	22.9	11.0
5	43.2	23.0	13.2
6	33.0—L	23.4	9.8—L
7	38.9	23.2	12.3
8	40.4	22.9	12.4
9	38.6	23.6	12.0
10	47.0	23.0	13.6
11	44.3	22.8	13.4
Average	41.70	23.01	12.37

Egg No. 2 had a constricted nipple at one end and No. 6 had a flesh-colored area covering about one-third of the egg. All other eggs were plain cream white, with smooth, parchment-like shells. Numbers 7 to 11, inclusive, were adherent in a single cluster but were separated for weighing and measuring. Several young had escaped from their shells when the clutch was examined on July 26, 1936, and the last emerged on July 27. Two eggs were not fertile.

No	Length	Weight
1	290	11.1
2	285	9.4- L
3	289	10.5
4	277-- L	10.8
5	300- H	11.1
6	282	11.0
7	295	12.3 - H
<hr/>		
Average (of 7)	288.2	10.89
8	232	7.8
9	216	5.5
<hr/>		
Average (of 9)	274	9.93

The last two specimens obviously were runts. In addition their sides were somewhat shrunken except in the region of the belly, which was noticeably swollen. They lived only a few days. The other specimens began eating DeKay's snakes, *Storeria dekayi*, and one another almost at once; eventually only one specimen remained.

Rhinocheilus lecontei Baird & Girard.

Eggs were found in the cage on July 1, 1935. The female was purchased from a dealer and its origin is unknown.

No.	Length	Width	Weight
1	37.0	15.9	7.1
2	36.2	16.0--H	6.7
3	37.2	16.0	6.6
4	41.0--H	15.4	7.2- H
5	35.6	15.8	6.5
6	30.1 - L	15.3--L	5.3- L
<hr/>			
Average	36.18	15.73	6.57

Natrix cyclopion floridana Goff.

Two specimens from Marion County, Florida, bore young in captivity.

I. Young born on July 27, 1936.

No.	Length	Weight
1	249—H	8.3—H
2	248	7.0
3	229	6.3
4	230	5.9—L
5	240	7.5
6	229	6.2
7	245	7.0
8	248	7.0
9	234	6.9
10	233	7.1
11	225	6.6
12	243	8.1
13	244	7.9
14	222—L	6.0
Average	237.07	6.99

This litter probably consisted of more than 14 specimens since some had escaped from the cage and were found on the floor. Number 4 had its hemipenes everted; No. 14 was dead. The pattern of the young snakes was more conspicuous than that of adults; it consisted of black reticulations on an olive-brown ground. Their bellies were plain yellow except for the antero-lateral edges of the ventrals, which were black.

II. Young born on August 7, 1936. Length of female, 1389 mm.; weight, 686.6 g.

No.	Length	Weight
1	245	9.0
2	259—H	9.2
3	241	7.6—L
4	257	9.1
5	250	8.9
6	244	8.4
7	245	8.0
8	240—L	8.7
9	246	8.7
10	251	9.6—H
Average	247.8	8.72

Natrix erythrogaster transversa (Hallowell).

A litter was born on September 5, 1933, to a female collected in Kansas and presented to the Toledo Zoological Park by Dr. Reeve M. Bailey. The parent measured 1071 mm. and weighed 335.1 g.

No.	Length	Weight
1	255	6.0
2	267	5.9
3	268	6.4 -H
4	256	6.1
5	250	5.6
6	267	6.0
7	262	6.1
8	268	6.4
9	257	6.2
10	240	6.2
11	264	6.1
12	261	6.1
13	266	6.3
14	267	6.3
15	258	5.8
16	255	6.0
17	265	5.9
18	271	6.3
19	271	5.7
20	265	5.5 -L
Average	263.15	6.05

An additional specimen (not recorded) was born dead. The living young might be described as follows:

Pattern (above) consists of a dorsal and lateral series of blotches alternating clear forward to the head. In the center of each light area, on the sides between the black blotches, is a large area of rose-brown, narrowly edged with white. Belly uniform white except for the antero-lateral edges of the ventrals, which are black.

These small snakes began eating chopped fish almost at once. As they grew they were measured and weighed at intervals. On December 9, 1933, they averaged 259.3 mm. and 6.61 g.; on April 5, 1934, 19 of them (one having died) averaged 306.8 mm. and 10.90 g.; on June 13, 1934, 331.6 mm. and 13.33 g. All but 3 had died by May 2, 1935, when the survivors averaged 420 mm. and 26.70 g. These snakes did not hibernate; they were kept warm and active over both winters.

Several young of this subspecies were born at the Toledo Zoological Park during September, 1930, to a female from New Braunfels, Texas. They grew rapidly in captivity on a diet of fish, but as a result of cannibalism the group eventually was reduced to one. This, a female, passed a large, red, infertile ovum on September 2, 1933, and two others on September 4, 1933. Thus it would appear that the snake was sexually mature at the age of three years. At that time it weighed 429.7 g. and measured 960 mm. in length. While it was still light in color, its pattern had become rather indistinct and the contrast between blotches and ground color was considerably lessened. The light crossbands between the dorsal blotches were the most prominent feature of the pattern.

Natrix septemvittata (Say).

Two females of this species from Detroit, Michigan, gave birth to young on August 23, 1938. Since both females were in the same cage it was impossible to determine how many each had borne.

No.	Length	Weight
1	212	2.8
2	221	2.6
3	222	3.3--II
4	215	2.6
5	222	3.2
6	223	3.3
7	227	3.1
8	226	3.2
9	225	2.8
10	218	2.7
11	216	2.6
12	206—I	2.3—I.
13	230--II	3.1
	----	----
Average	220.2	2.89

Another female from Delaware County, Pennsylvania, bore 2 young and passed 2 dead embryos and 2 infertile ova on August 22, 1938. The female weighed 52.9 g. and measured 688 mm. Data on the 2 living young are:

No.	Length	Weight
1	168	1.4
2	206	2.5
	----	----
Average	187	1.95

No. 1 was deformed.

Natrix sipedon pictiventris Cope.

Young were born on August 2, 1936, to a specimen from near Palmetto, Florida, collected by the late C. C. Goff. The female weighed 368.9 g. and measured 771 mm. in length. Most of its tail was missing.

No.	Length	Weight
1	211	3.3
2	213	3.4
3	194	3.2
4	215	3.5
5	206	3.5
6	208	4.0
7	217	3.9
8	213	4.2
9	215	3.7
10	180	L. 2.9- - L.
11	210	4.3
12	211	4.0
13	199	3.7
14	205	3.4
15	223	H 3.8
16	217	4.2
17	201	4.0
18	200	3.9
19	206	4.4- - H
20	199	3.7
21	221	3.7
22	192	3.2
23	206	3.7
24	204	3.5
25	218	4.1
<hr/>		
Average	207.36	3.73

No. 24 and No. 25 were dead

Thamnophis sirtalis sirtalis (Linnaeus).

A specimen from Philadelphia, Pennsylvania. Young born on August 4, 1936. Length of female, 706 mm.; weight, 92.2 g.

No.	Length	Weight
1	143	1.1
2	142	0.9 I.
3	156	1.1
4	155	1.0
5	156	1.2 II
6	155	1.0
7	162	1.2
8	164	1.2
9	155	1.1
10	157	0.9
11	147	1.1
12	149	1.0
13	162	1.1
14	153	1.1
15	164	1.2
16	158	1.0
17	150	1.1
18	165	1.2
19	161	1.1
20	160	1.1
21	168	1.0
22	170- H	1.1
23	158	1.0
24	166	1.1
25	152	1.0
26	160	1.2
27	158	1.1
28	157	1.1
29	149	1.0
30	155	1.0
31	140 I	0.9
Average	156.35	1.07

No. 12 had a deformed back. No. 31 was dead.

Crotalus viridis viridis Rafinesque.

Young born to two females received from South Dakota, collected by A. M. Jackley in August, 1938.

1. Born on September 7, 1938. Parent weighed 297.4 g. and measured 946 mm. in length, to the base of the rattle.

No.	Length	Weight
1	281	14.9
2	282	13.8—I
3	286	15.1
4	290—H	15.2
5	273	14.2
6	274	14.3
7	251—I.	14.1
8	259	14.2
9	270	14.8
10	279	15.6—H
11	277	15.5
Average	274.73	14.7

The eyes of all were overcast, indicative of an approaching moult.

II. Young born on September 10, 1938; two dead embryos also passed. Female undertermined; several others in cage.

No.	Length	Weight
1	256	14.8
2	271—H	15.6—H
3	237—L	11.6—L
4	249	12.8
5	253	12.8
Average		13.52

The "button" was included in measuring the young of both litters.

Sternotherus odoratus (Latreille).

A turtle of this species was collected early in June, 1936, by Byron Gardner, Jr., who found it in South Carolina directly across the Savannah River from Augusta, Georgia. It deposited 2 eggs on June 22.

No.	Length	Width	Weight
1	25	15.1	3.6
2	23.2	15.4	3.5
Average		15.25	3.55

On October 2, 1936, a baby was found walking about in the hatching media. That it may have emerged at some time previous is indicated by the fact that the other egg also had hatched, but the young had died and was badly desiccated. Data on the living one are as follows:

Carapace		Depth of	Plastron	Weight
Length	Width	Shell	Length	
22	18.9	12	15.8	2.2

Chelydra serpentina serpentina (Linnaeus).

A large snapper collected 3 miles north of New Castle, Delaware, on April 24, 1936, deposited 3 eggs in its tank on June 22, 1936.

No.	Diameter	Weight
1	27.2	10.8—H
2	26.8—L	9.7—L
3	29.5—H	10.7
Average		10.4

Since the nature of the tank prevented this turtle from nesting, the 3 eggs doubtless represent only a fraction of the entire complement. The specimen was transferred to a spacious, out-door enclosure but whether other eggs were laid was not determined.

Terrapene carolina carolina (Linnaeus).

A set of eggs probably found near Philadelphia, was given to the Philadelphia Zoological Garden by an anonymous donor. Young hatched on September 1 and 2, 1938.

No.	Carapace		Depth of Shell	Weight
	Length	Width		
1	34.6	33.3	16.6—L.	7.9
2	33.3—L	32.1—L.	16.7	7.8
3	34.9—H	33.5	17.0—H	8.4—H
4	33.7	33.4—H	16.8	7.6—L.
Average	34.13	33.15	16.78	7.93

Pseudemys floridana ssp.

A female from central Florida laid 2 eggs in its tank on June 7, 1936.

No.	Length	Width	Weight
1	33.0	24.3	9.2
2	35.7	24.5	8.7
Average	34.35	24.4	8.95

As with the specimen of *Chelydra s. serpentina* above, conditions were not optimum for laying and the 2 eggs doubtless are but a part of the number the turtle might have been expected to lay.

Testudo tornieri Siebenrock.

Four of these tortoises were secured from a dealer on August 7, 1935. One of them, weighing 375.9 g., carapace length 144 mm., carapace width 106 mm., and depth of shell 38 mm., deposited an egg on January 9, 1937. This weighed 33.5 g. and measured 48 mm. in length by 28 mm. in width. As Loveridge (1928, p. 51) has noted, this remarkable turtle has a complement of only a single egg.

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4.

Occlusion of the Venom Duct of Crotalidae by Electrocoagulation:
an Innovation in Operative Technique.¹

DUVAL B. JAROS

Riverside, Illinois.

(Text-figure 1).

An article by Tait² on the surgical removal of the venom glands of rattlesnakes prompted Mr. Emil Rokosky of the Chicago Zoological Park to suggest the use of electrocoagulation on the venom gland. It was thought, however, that occlusion of the duct would be a less drastic procedure than removal of the gland. In addition, conservation of the gland would permit interesting experiments and histologic studies. The immediate problem presented was the development of the technical details of a rapid operation which would occlude the duct, preserve the gland and result in minimum injury to the snake. In the procedure here outlined, electrocoagulation is employed.

Electrocoagulation produces destruction of tissue by heat, and corresponds to the solidifying of the white of an egg during boiling. The heat of electrocoagulation, however, is not conducted but is induced within the tissue itself, which insures coagulation without even surface carbonization. The coagulum is sterile and simulates a scab, nature's own wound covering. Sterility, firmness and pliability of the coagulum permit healing without scarring.

Essentials of an electrocoagulating device are two electrodes and a high frequency current. The electrodes may be in the form of a single duoterminal instrument, a body-plate and a point, or as in the present experiment, two separate uniterminal instruments with one serving also as the probe for securing the duct.

The high frequency current alternates at about one million cycles per second. Suitable currents can be obtained from simple spark-gap or thermionic tube apparatuses sold by all physiotherapy equipment dealers. The coagulating current of 800 kilocycles, 150 milliamperes and 2000 volts, seals the severed ends of the duct, and is therefore preferable to the cutting current.

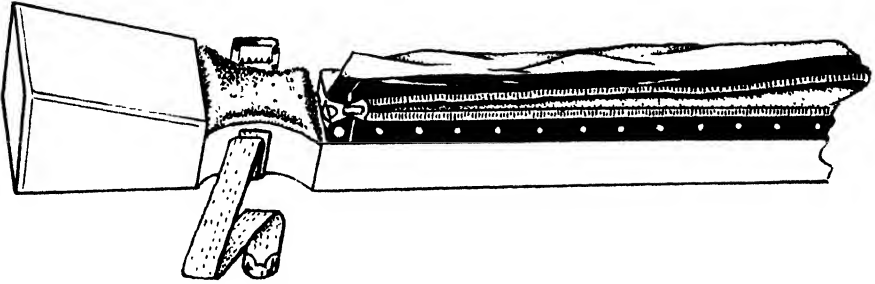
In the operation, several innovations employed made general anaesthesia unnecessary and facilitated single-handed performance with relative safety to the operator and the snake. The first device, an operating board (Text-fig. 1) was designed to hold the snake firmly and prevent it from thrashing. The board was fitted with a neck pad, strap and a thin rubber restraining flap for the body. When in use, this flap was drawn over the snake and attached along the opposite edge of the board by a zipper running its entire

¹ Presented at a meeting of the Amateur Herpetologist Group of the Chicago Academy of Sciences, June 15, 1939, and at the annual meeting of the American Society of Ichthyologists and Herpetologists, Chicago, September 14, 1939.

² *Copeia*, 1938:1.

length. Pressed down by the restraining sheet which yields to its struggles, the snake cannot crawl. This operative convenience can be augmented by having the surface of the board on which the snake rests very smooth or covered with yielding rubber similar to the overlying restraining sheet.

A second aid was the surgical skin clip or Michel clip. These clips, small strips of metal clawed at each end and preferably bent into a V shape, when pressed point to point, firmly grasp any interposed tissue. Applied to the snake's lips, they hold the snake's mouth shut and make handling relatively safe without the use of general anaesthesia.



Text-figure 1.

Operating board designed to hold a snake firmly while the venom duct is occluded.

Another innovation was an improvised scalpel which proved, for my purpose, to be superior to any other obtainable. These scalpels were made from slivers of the cutting edges of Gillette "Thin Blades," broken off with pliers and clamped in ordinary artery forceps. With the forceps serving as handles, these tiny bayonettes afforded a generous supply of extremely sharp, delicate and inexpensive knives.

THE OPERATION.

The snake, grasped behind the head, was fastened to the operating board, and Michel clips were clamped on the lips; one on each side below the pit. Care was taken not to include the mandible.

At this time, if desired, a local anaesthetic may be injected at the site of the incision. A 2% procain borate solution was used. Almost immediately after the injection a quarter-inch incision was made just below the eye and on a level with the pit. Through this small incision the duct was secured and drawn out with a blunt curved probe. When clear of the surrounding tissue, it was coagulated sufficiently to sever it. The severed ends were dropped back into place and the wound was touched with tincture of merthiolate. The wound was so small, and there was so little trauma, that sutures were unnecessary and healing was remarkably rapid. In many cases it was difficult to locate the site of incision after one week.

As the snake is not deprived of glands or fangs, the outward appearance of the head remains unaltered. In the specimens under observation no change in disposition was noticed; feeding remained regular in those which ate regularly before treatment. Each specimen was tested weekly by allowing it to bite a rabbit. In every case the result was negative. A cotton-mouth moccasin, (*Agkistrodon piscivorus*) in good health forty-five weeks after treatment and eating well, was nevertheless unable to inflict other than mechanical injuries when biting. Deaths resulted from causes other than the operation—from mouth rot and intestinal disorder.

The obstructed glands taken from snakes three, seven and eight weeks, and ten months, after treatment were sectioned for microscopic examination. The sections were studied by Dr. George J. Rukstinat, Associate Professor of Pathology at Rush Medical College. He found large acinar spaces filled with secretion, and lined by cells which evidently became cuboidal as a result of the retained venom; but even the compressed cells showed little signs of atrophy. In portions of the sections normal columnar cells survived. Nuclei and cytoplasm were demarcated clearly. Confluence of acini in some regions seemed apparent from the remnants of acinar walls which projected into the lumens of the cyst-like spaces. Many cells contained clear or slightly stippled vacuoles, the character of which is being investigated.

The histological evidences of cell viability were corroborated by the sub-cutaneous injection into mice of secretion from the glands of one snake which was killed ten months after occlusion of the duct. Minute quantities (0.02 cc.) of this secretion proved fatal to mice in four hours, and induced the usual changes of a general haemolysis and of local necrosis.

The potentialities for study of the venom gland through this method are numerous. Perhaps some internal absorption of secretion occurs; or perhaps some specialized cells elaborate components of venom as do specialized cells in organs such as the pancreas.

SUMMARY.

A method of rendering venomous serpents harmless is presented. Electrocoagulation is used to prevent, by the destruction of a portion of the duct, the escape of venom from the gland and its passage to the fang. The operator can manage, unassisted and with safety, the entire procedure. The snake is but slightly injured and is not disfigured. The desired results are apparently permanent. The habits of none of the thirty-six snakes treated seemed in any way effected by the operation, even after forty-five weeks. The operation was successfully performed on crotalids ranging in size from eight inches to four feet.

In the performance of the operation three innovations were introduced: a practical device for holding the snake, a cheap and efficient operating knife, and the use of Michel surgical clips to eliminate all danger of being bitten.

I wish to express my grateful acknowledgement to Dr. George J. Rukstinat, to Mr. Walter L. Necker of the Chicago Academy of Sciences, and to Mr. Emil J. Rokosky, for advice and encouragement; and to my father, Dr. Joseph F. Jaros, for his help with the technical aspects of the work.

5.

Eastern Pacific Expeditions of the New York
Zoological Society. XVII.

A Review of the American Fishes of the Family Cirrhitidae.¹

JOHN TEE-VAN

Department of Tropical Research, New York Zoological Society

(Plate I; Text-figures 1-4).

[This is the *seventeenth* of a series of papers dealing with the collections of the Eastern Pacific Expeditions of the New York Zoological Society made under the direction of Dr. William Beebe. The present paper is concerned with specimens taken on the Templeton Crocker Expedition (1936), the Eastern Pacific *Zaca* (1937-1938) and the *Arcturus* Oceanographic (1925) Expeditions. For data on localities, dates, dredges, etc., of these expeditions, refer to *Zoologica*, Vol. VIII, No. 1, pp. 1-45 (*Arcturus*); *Zoologica*, Vol. XXII, No. 2, pp. 33-46 (Templeton Crocker); and *Zoologica*, Vol. XXIII, No. 14, pp. 278-298 (Eastern Pacific *Zaca*).]

CONTENTS.

	Page		Page
Introduction	53	<i>Cirrhitus rivulatus</i> (Valenciennes)	54
Key for the differentiation of the American		<i>Cirrhitichthys</i>	58
genera (Family Cirrhitidae)	54	<i>Cirrhitichthys corallicola</i> new species	58
<i>Cirrhitus</i>	54	<i>Pseudocirrhitus</i>	61
		<i>Pseudocirrhitus pinos</i> Mowbray	61

INTRODUCTION.

For many years the only representative of the family Cirrhitidae known from the Americas was the west coast *Cirrhitus rivulatus* (Valenciennes). In 1927, however, Mowbray described a species from the Isle of Pines, Cuba, establishing a new genus, *Pseudocirrhitus*, for his fish, and marking the first West Indian record for the family. During the 1937-1938 expedition of the Department of Tropical Research of the New York Zoological Society along the west coast of Mexico and Central America, still another form was found; it is described as a new species in this paper. Specimens of all three species have been examined and are reviewed and described herewith.

In the light of the recent discovery of a cirrhitoid fish in West Indian waters, the finding of a closely related form on the west coast of America tends to explain the apparent isolation of the Atlantic fish and provides another link in the chain of evidence that demonstrates the close relationship of the fishes of the Atlantic and Pacific sides of tropical American waters.

¹ Contribution No. 590, Department of Tropical Research, New York Zoological Society

For an explanation of the position of localities mentioned in this paper, see Text-fig. 4.

I am indebted to Dr. Leonard P. Schultz of the U. S. National Museum and Prof. Albert E. Parr of the Peabody Museum, Yale University, for the loan of specimens, and to Miss Janet B. Wilson, who made the drawings used in this paper.

Family Cirrhitidae.

Key for the differentiation of the American genera.

- 1a. Scales on the cheek very small, 16 to 20 rows from eye to edge of preopercle (Pacific) *Cirrhitus*.
- 1b. Scales on the cheek large, 4 to 5 rows from eye to edge of preopercle.
 - 2a. Scales absent on nape and interorbital space; a small patch of scales behind and between the anterior nostrils (Pacific) *Cirrhitichthys*.
 - 2b. Scales present on nape and interorbital space. (Atlantic) *Pseudocirrhitus*.

Cirrhitus Lacépède, 1803.

Genotype by monotypy, *Cirrhitus maculatus* Lacépède, Lacépède, 1803, Hist. Nat. des Poiss., 5: 2.

Cirrhitus rivulatus (Valenciennes).

(Plate I, Text-fig. 1).

Proportions in Percentage of the Standard Length, and Counts: Depth 34-36 (2.4-3)²; head 38-40 (2.46-2.75); eye 7.7 in fish of 119 to 182 mm., 9.2 in 65 mm. fish, 11-11.4 in 30 to 35 mm. fish (3-5.7); snout 11-14.7 (2.3-3.1); maxillary 13.6-17.6 (2.1-2.8); interorbital space 5-6.5 (5.4-7.66); pectoral length 25.4-28.6 in fish of 119 to 182 mm., 32.2-34 in 31 to 65 mm. fish; pelvic length 20-23; snout to 1st dorsal fin 38-41; snout to 2nd dorsal fin 64-68; snout to anal fin 68-73; snout to pectoral fin 34-38; snout to pelvic fin 45-51; 1st dorsal height 11.7-14.6; 2nd dorsal height 12.2-15.4; anal height 17.4-20.6. Dorsal fin X, 11 or 12; anal fin III, 6 or 7; pectoral fin with 14 rays, the uppermost and the lower 7 (rarely 8) simple; scales: 5½ to 6½ from origin of 1st dorsal fin to lateral line, 46 to 49 in a longitudinal series, 12 to 14 scales from lateral line to origin of anal fin, 7 to 8 predorsal scales; gill-rakers, 5 to 6 on upper limb and 10 to 11 on the lower limb of the first arch.

Body compressed, sturdily and heavily built, the caudal peduncle deep. Anterior profile strongly convex, especially in larger individuals, the eye entering the profile very slightly. Scales present on the body, absent on the head except for the preopercle, which is very finely scaled, and the opercle which has scales on its anterior part similar to those of the body; somewhat smaller scales on the posterior flap of the opercle. Lateral line continuous, the openings of the canals tilted upward.

Interorbital space concave; a low longitudinal crest on the nape; preopercle broadly rounded, its upper portion finely serrate, the serrations most conspicuous in small specimens; opercle with an obtuse flap extending backward over the pectoral base. Branchiostegal rays 6, the innermost one very small; the branchiostegal membranes broadly united but free from the isthmus; mouth low, the lips thick in large specimens; maxillary extending backward to the vertical of the posterior border of the orbit in large fish and to the center of the orbit in small fish. Upper jaw with small, rather widely spaced canines, the posterior tooth and three or four near the symphysis en-

² Figures in parentheses are proportions stated in terms of times in the head or standard length.

larged; inside of these teeth is a band of smaller teeth, the band widest anteriorly, becoming narrower laterally and vanishing posteriorly. Lower jaw with similar teeth but with two or three of the outer canine-like teeth near the center of each side of the jaw enlarged. Tongue large, wide and free anteriorly. Gill-rakers short, covered with fine asperities.

Spinous dorsal fin rather low, the spines increasing in size to the 5th and 6th, then decreasing, the ultimate spine longer than the penultimate; soft dorsal fin higher than the spinous; caudal fin truncate or slightly concave; anal fin with the second spine largest and heaviest, the rays long, twice the length of the spines; pectoral fin with its lower rays considerably swollen, especially in large individuals, the 5th and 6th from the bottom longest, posterior edge of the branched rays oblique, the uppermost simple ray shortest of all; pelvic fins originating under the center of the adpressed pectoral fin, the tip of the pelvics reaching to the vent or slightly beyond.

Color: During growth there is considerable change in the coloration of this species, the principal alterations being caused, first, by the breaking up of the simple vertical bands of the young into groups of spots bordered with darker and lighter, the spots often acquiring a different basal color; second, the shift from the pearly-gray ground color of the very young to the browns or greenish-browns of the adults; third, the loss of scarlet on the upper anterior surface markings of the head and the disappearance of the scarlet, black and gray spinous dorsal fin.

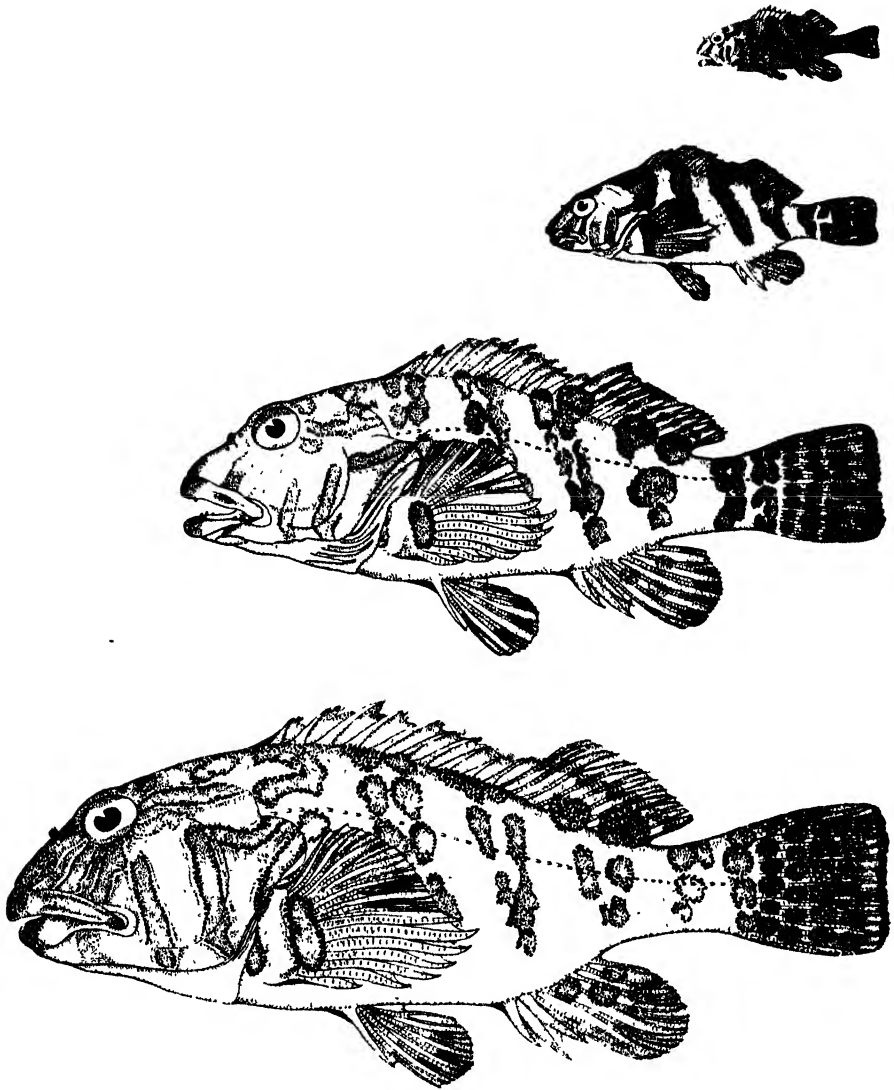
The original description of the young, (nominal *Cirrhitus betaurus*), given by Gill in 1862, agrees excellently with our similar-sized specimens (35 mm.). Gill's description is appended here: "The color is *whitish* on the body, blackish on the shoulders and from the dorsal fin to the eyes, and with four complete, oblique, blackish bands; the first under the middle of the spinous dorsal; the second under the last spine; the third under the middle of the soft dorsal, and the fourth encircling the caudal peduncle. The head has three lateral bands, one on the preorbital region, a second on the cheek, and a third on the posterior margin of the preoperculum. The operculum has a longitudinal oblong spot. The chin has four spots forming the angles of a rhomb, and there is another one behind, on the branchiostegal membrane near the margin. The spinous dorsal is margined with blackish, and the two bands beneath more or less ascend on it; anal blackish. The caudal has a blackish B-shaped mark and a band at its base divided by the lateral line. The pectoral is dusky, with a black spot at its base nearly surrounded by a clear area, and separated from a spot in front of the base. The ventrals are blackish, with nearly transparent sides and margin."

A color plate made in the field from a living 35 mm. specimen shows the following slight differences from this color description: The ground color is pearly gray, the spinous dorsal fin is scarlet with a blackish narrow upper border, the vertical body bands being continued upward onto the fin. All of the dark markings on the head and nape have a central core of reddish-brown. Jordan (*Fishes of Sinaloa, Proc. Cal. Acad. Sciences*, (2) 5: 473) states of similar-sized small individuals: "First dorsal fin bright orange red in life; second reddish; cross bands on body black."

In a 65 mm. standard length fish the ground color is much duller and the bands on the sides are starting to break up into spots. This is especially noticeable on the dorsal surface of the body near the dorsal fin.

In our series the next largest specimen (119 mm.) has the pattern and coloration of all of the remaining larger specimens.

The adults may be described as follows, the description being combined from other descriptions and our own observations. Color of body dark greenish- or yellowish-brown, occasionally more ochraceous brown on the lower head and belly (dark gray: Fowler). Dark brown, spots and bands, occasionally becoming yellowish-brown, usually bordered first with darker brown or



Text-figure 1.

Cirrhatus rivulatus Valenciennes. Specimens of 35, 65, 142 and 182 mm. standard length, showing the changes of pattern with age.

black and then with pale blue, distributed as follows: three narrow bands crossing the interorbital space; two to three bands from the eye to the maxillary or premaxillary; a saddle-like transverse band on the nape posterior to the eye, in the center of which, posteriorly, is a small circular spot; on the nape are three longitudinal short bars, one on the mid-dorsal line and one on either side of this; a band from eye to supra-scapular; one from eye to upper border of the preopercle; a vertical band on the preopercle anteriorly and another on the posterior border; an upwardly ascending band from the upper edge of the preopercle toward the upper tip of the opercle; a short vertical band on the base of the pectoral fin and another similar one

on the pre-pectoral region. Body with five upright oblique bands of similarly colored and bordered broken spots, the bands extending onto the spinous and soft dorsal fins; in addition there is a similar band on the posterior end of the caudal peduncle. Caudal fin with sub-circular brown spots bordered with darker brown and light blue, the spots roughly forming vertical and semicircular vertical lines; this arrangement is not always apparent in large specimens. In some descriptions the tail is described as being dark with a network of pale blue reticulated lines. Dorsal fin dark brown, somewhat mottled with continuations of the bars of the sides of the body; pectoral fins dusky; anal fin dark brown, sometimes green basally, with two to five prominent spots similar to those on the body on its posterior portion; pelvic fins dusky, especially toward the tip, sometimes olive basally, gray-black terminally.

Iris in life (327 mm. fish) olive green above and below with a broad silvery zone extending longitudinally, within which are two rounded spots in front and two more behind the pupil. A narrow green area immediately surrounding the pupil.

Range: Pacific mainland from Lower California and the Gulf of California southward to Panama (Mexico: Cape San Lucas, Gulf of California, Mazatlan, Sihuatanajo, Acapulco; Nicaragua: Corinto; Costa Rica: Piedra Blanca Bay, Uvita Bay; Panama: Panama); Revillagigedo Islands (Clarion Is., Socorro Is.); Galápagos Islands (Hood Is., James Is., Tower Is.); Malpelo Island.

Local Distribution: A rocky reef and tidepool species, hiding in crevices and darting out for prey.

Method of Capture: Hook and line baited with bait or with a shiny piece of metal, traps, poisoning in tidepools.

Size: Grows to 17½ inches. A 327 mm. (12½ inches) fish weighed 3 pounds and a 450 mm. (17½ inches) fish weighed 5 pounds.

Study Materials: 8 specimens from 31 to 450 millimeters, from the following localities: Nicaragua: Corinto; Costa Rica: Piedra Blanca Bay, Uvita Bay; Galápagos Islands: Tower Island. In addition, water-glass sight records were made of this species at the following places: Mexico: Sihuatanajo, Acapulco; Clarion Island

References: *Cirrhitus rivulatus* Valenciennes, Voyage autour du Monde, sur la fregatte "La Venus," tome 5, Ichthyologie, 1855: 309, plate 3, fig. 1 (Description, color, poor plate: **type locality, Galápagos Islands**); Günther, Catalogue of the Acanthopterygian Fishes in the Collection of the British Museum, 2, 1860: 519 (Short description); Jordan, D. S. and Gilbert, C. H., List of Fishes collected at Mazatlan, Mexico, by Charles H. Gilbert, *Proc. U. S. Nat. Mus.*, 2, 1882 (1883): 108 (Check-list, name only); Jordan, D. S., A list of the fishes known from the Pacific coast of tropical America, from the Tropic of Cancer to Panama, *Proc. U. S. Nat. Mus.*, 8, 1885 (1886): 381 (Check-list; Cape San Lucas, Galápagos Islands); Jordan, D. S. and Evermann, B. W., The Fishes of North and Middle America, *Bull. U. S. Nat. Mus.*, 47 (2), 1898: 1491 (Description, color, range, short synonymy); Jordan, D. S. and McGregor, R. C., List of fishes collected at the Revillagigedo Archipelago and neighbouring islands, *Rept. U. S. Fish Comm.* for 1893 (1899): 283 (Clarion and Socorro Islands); Jordan, D. S. and Evermann, B. W., The Fishes of North and Middle America, *Bull. U. S. Nat. Mus.*, 47 (4), 1900: plate 227, fig. 576 (figure); Pellegrin, J., Poissons recueillis par M. Leon Digueat dans le Golfe de Californie, *Bull. Mus. Hist. Nat. (Paris)*, 7, 1901: 163 (Gulf of California); Gilbert, C. H. and Starks, E. C., The Fishes of Panama Bay, *Mem. Calif. Acad. Sci.*, 4, 1904: 139 (Panama; restates Günther's 1868 record); Beebe, W., Galapagos, World's End, G. P. Putnam's Sons, New York and London, 1924: plate 5 (colored figure); Ulrey, A. B., A check-list of the fishes of Southern California and Lower California, *Journ. Pan-Pacific Res. Inst.*, 4 (4), 1929: 18 (Check-list only; Cape San Lucas); Terron, C. C., Lista de los peces de los costas de la Baja California, *Ann. Inst. Biol., Univ. Nac. Auton. Mexico*, 3, 1932: 79 (Check-list, name only, Cape San

Lucas); Breder, C. M., Jr., Heterosomata to Pediculata from Panama to Lower California, *Bull. Bingham Oceanogr. Coll.*, **2** (3), 1936: 37 (Unknown locality).

Cirrhitus rivulatus: Gill, T., Synopsis of the family of Cirrhitoids, *Proc. Acad. Nat. Sci. Phila.*, 1862: 107 (Name, synonymy, range); Gill, T., Catalogue of the fishes of Lower California, in the Smithsonian Institution, collected by Mr. John Xantus, *Proc. Acad. Nat. Sci. Phila.*, 1862: 259 (Cape San Lucas, Lower California); Snodgrass, R. E. and Heller, E., Shore fishes of the Revillagigedo, Clipperton, Cocos and Galapagos Islands, *Proc. Wash. Acad. Sci.*, **6**, 1905: 385 (Galapagos Islands, range, few proportions); Beebe, W., The Arcturus Adventure, G. P. Putnam's Sons, New York and London, 1926: 150 (Hood Island, Galapagos; method of capture). See p. 434 for specific determination; Jordan, D. S., Evermann, B. W. and Clark, H. W., Check list of the fishes and fishlike vertebrates of North and Middle America north of the northern boundary of Venezuela and Colombia, *Rep. U. S. Comm. of Fish.* for 1928 (1930): 358 (Check list, range); Fowler, H. W., The Fishes of the George Vanderbilt South Pacific Expedition, 1937, *Acad. Nat. Sci. Phila., Monograph No. 2*, 1938: 15 (Description, color; Malpelo Island), 53, (Note on color, proportions; James Island, Galapagos), 257, (check list).

Cirrhitus betaurus: Gill, T. N., Catalogue of the fishes of Lower California in the Smithsonian Institution, collected by Mr. John Xantus, *Proc. Acad. Nat. Sci. Phila.*, 1862: 259 (Original description, color; **type locality: Cape San Lucas, Lower California**); Jordan, D. S. and Gilbert, C. H., Catalogue of the fishes collected by Mr. John Xantus at Cape San Lucas, which are now in the United States National Museum, with descriptions of eight new species, *Proc. U. S. Nat. Mus.*, **5**, 1882 (1883): 371 (Synonymized with *Cirrhitus rivulatus*).

Cirrhitichthys rivulatus: Günther, A., An account of the Fishes of the States of Central America, based on collections made by Captain J. M. Dow, F. Godman, Esq., and O. Salvin, Esq., *Trans. Zool. Soc. London*, **6** (7), 1868: 387 (Check list); Galapagos Islands, Panama), 421, plate 86, fig. 4 (Panama, description, figure).

Cirrhitichthys betaurus: Jordan, D. S., The fishes of Sinaloa, *Proc. Calif. Acad. Sci.*, (2) **5**, 1895: 472 (Relationship of *betaurus* and *rivulatus* discussed, color, Mazatlan); Jordan, D. S. and Evermann, B. W., The Fishes of North and Middle America, *Bull. U. S. Nat. Mus.*, **47**, 1898: 1492 (Description, color, range); Ulrey, A. B., A check-list of the fishes of Southern California and Lower California, *Journ. Pan-Pacific Res. Inst.*, **4** (4), 1929: 18 (Check list only. Cape San Lucas); Terron, C. C., Lista de los peces de las costas de la Baja California, *Ann. Inst. Biol., Univ. Nac. Auton. Mexico*, **3**, 1932: 79 (Check list, name only; Cape San Lucas).

***Cirrhitichthys* Bleeker, 1856.**

Genotype by original designation *Cirrhitichthys graphidopterus* = *Cirrhitichthys aprinus* Cuv. and Val.; Bleeker, *Naturk. Tijdschr. Nederl.-Indie*, Deel X (new series, Deel VII) 1856: 474. The generic description was published in 1857 by Bleeker, *Vischfauna van Ambonia, Acta Soc. Sci. Indo-Nederl.*, **2**, 1857: 39.

***Cirrhitichthys corallicola* sp. nov.**

(Text-figure 2).

Type: Holotype, No. 28,710a, Eastern Pacific Zaca Expedition of the Department of Tropical Research, New York Zoological Society; Gorgona Island, off the Pacific coast of Colombia, South America (Lat. 2° 58' N., Long. 78° 11' W.), in coral, March 30, 1938; standard length 58 mm. *Paratypes*: 32 specimens, No. 28,710, same locality and date as the holotype, 22 to 59 mm. standard length. Types in the collections of the Department of Tropical Research, New York Zoological Society.

Measurements in Percentage of the Standard Length, and Counts: Measurements of the holotype: Depth 36.6 (2.7); head 34.5 (2.9); eye 8.4

(4.1 in head); snout 11.2 (3.1 in head); interorbital space 5.7 (6.1 in head); maxillary 13.3 (2.6); pectoral fin length 33.5 pelvic fin length 24; snout to origin of 1st dorsal fin 33.5; snout to 2nd dorsal fin 64; snout to origin of anal fin 68; snout to pectoral fin 32; snout to pelvic fin 45; 1st dorsal height 17.6; 2nd dorsal fin height 26.8; anal fin spine height 21.6.

Measurements of 10 individuals, 34 to 58 mm. standard length, including those of the holotype: Depth 33-39.5 (2.6-2.9); head 34.2-39 (2.5-2.9); eye 7.8-10.9 (4.1-4.5); snout 10.2-12.4 (3.1-3.5); maxillary 12.3-14.2 (2.6-2.9); interorbital space 4.4-6.1 (6.1); pectoral fin length 31-37; pelvic fin length 23.7-26.3; snout to origin 1st dorsal fin 31.5-37; snout to 2nd dorsal fin 62-65; snout to origin of anal fin 65-72; snout to pectoral fin 32-36; snout to pelvic fin 42-49; 1st dorsal height 16-19; 2nd dorsal height 23-29; anal fin height (spine) 20-22. *Counts*: dorsal fin X, 12; anal fin III, 6; pectoral fin with 14 rays, the uppermost ray and the lowermost 6 or 7 simple; scales 43-45 in a lateral series, 4 from origin of dorsal fin to lateral line, 9 or 10 from lateral line to origin of anal fin; gill-rakers 3 to 5 on upper limb, 9 to 11 on the lower limb of the first gill-arch, the lowermost two rudimentary; vertebrae 10 plus 15 plus 1.

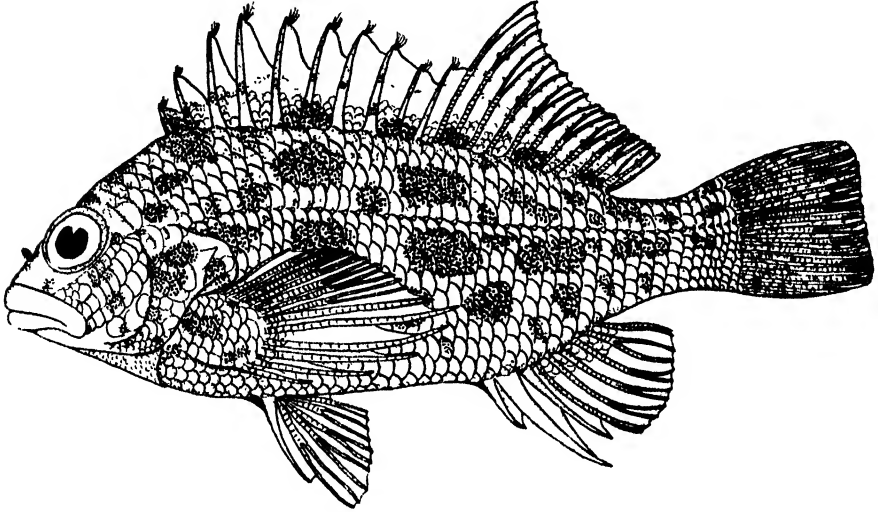
Body compressed, the head obtusely pointed, the greatest depth at $\frac{1}{2}$ the length of the pectoral, depth of caudal peduncle 13.3% of the length. Anterior profile at a 45 degree with the axis of the body, with a slight notch just above the orbit, the latter entering the profile. Upper profile from origin of dorsal fin to the 7th spine straight, the profile then gently curving toward the peduncle. Lower profile from snout to beneath base of pelvic fins at a considerable angle to the line of the abdomen.

Scales cycloid, absent on the head with the exception of the opercles and a small patch between the posterior nostrils; lips naked. Four oblique rows of scales on the preopercle from the eye to the rounded angle of the preopercle. Scales present on the opercles and on the branchiostegal membranes immediately beneath the isthmus; the latter scales are very small. Scales extending on the bases of the spinous dorsal fin and on the membranes of the soft dorsal and anal fins. Lateral line continuous, the tubes short and opening upward; nape with a large number of tubes.

Head obtusely pointed, the eye entering dorsal profile; interorbital space concave, the supraorbital ridges prominent, especially posteriorly; anterior nostril circular, with a short tube, nearer eye than snout and with a 5-fingered fleshy tentacle on its posterior border; posterior nostril with a raised border internally and anteriorly, placed close to the orbit; preopercle broadly rounded with 17 to 18 short but strong serrae, the uppermost slightly longer than the lower; opercle ending in an obtuse flap and with two flat spines, the lower much larger and more evident than the upper; branchiostegal rays 6, the innermost one on each side very small; branchiostegal membranes broadly connected but free from the isthmus; mouth small, the lips fleshy; maxillary extending to below the center of the orbit, the maxillary almost completely hidden beneath the suborbital. Teeth of the upper jaw with an outer row (20 to 21 on each side) of small, recurved canines, two on each side of the isthmus considerably larger and stronger than the others, the posterior teeth of the jaw slightly larger than their fellows; behind this outer row is a villiform band of small teeth, widest anteriorly, becoming narrower as it progresses backward. Lower teeth similar to those of the upper jaw, except that on the middle of the side of each jaw there is a group of enlarged canines; anterior to these the teeth are similar in size to those of the upper jaw, posterior to the enlarged group the teeth are quite small. The internal band of villiform teeth on the lower jaw extends backward only as far as the anterior tooth of the lateral enlarged canines. Vomer and palatines with villiform teeth, the teeth of the vomer in a broadly arched band. Gill-rakers small and short.

Dorsal fin with the 3rd, 4th and 5th spines highest, the upper anterior

edge of each interspinal membrane with a series of 8 to 10 dermal tentacles; soft dorsal high, the anterior two rays elongate and forming a slight lobe. Anal fin high, the second spine longer and heavier than the others, its length 1.5 in the head, length of the 1st spine 1.9 in the second, length of the third spine 1.3 in the second. Caudal fin truncate. Pelvic fins in close juxtaposition, their origin beneath the anterior 2/5ths of the pectoral fin, the tips of the pelvics extending to the vent. Pectoral fin with 14 rays, the uppermost one unbranched, the six lowermost (rarely the 7th) simple and unbranched, slightly swollen and with their tips free from membrane; 5th from bottom ray longest (1.15 in the head in the type), the 4th and 6th next longest.



Text-figure 2.

Currhitichthys corallicola Tee-Van. Drawing of the type, 58 mm. standard length.

Color: In life the general body color is orange yellow with a pinkish or lavender cast, heavily covered with dark orange or red spots placed somewhat in alternate oblique upright rows of larger and smaller spots, the spots extending onto the lower portion of the dorsal fin; similarly colored spots on the head, snout and base of the pectorals are much smaller than those on the body. Dorsally and posteriorly the spots become brighter red in color. Snout reddish. Dorsal fin transparent yellow, mottled with brownish, the tips of the spines and the tentacles on the interspinous membranes scarlet; caudal fin yellow mottled with dusky; pectoral, pelvic and anal fins transparent yellow, the latter somewhat dusky. Iris golden red.

In the Gorgona Island specimens the spots are exceptionally well-marked and clean cut. In many of the specimens from more northerly localities, the spots tend to merge and thus produce irregular vertical bands. This condition is especially noticeable in a 30 mm. fish from Acapulco, less so in some others.

In preservative our specimens have become yellow with brownish and gray spots, the pattern of the body being retained. In two specimens from the Pearl Islands, Panama (Vanderbilt Collection) there remain only vague traces of the spots on the body.

Range: Found by us from Sihuatanejo, Mexico, southward along the coast to Gorgona Island, Colombia. (Mexico: Sihuatanejo Bay, Acapulco; Costa Rica: Port Parker, Port Culebra; Panama: Bahia Honda, Pearl

Islands (Vanderbilt Alva 1938 Expedition); Colombia: Gorgona Island). The majority of the specimens seen and taken by us were found in the interstices of coral. The fishes were rarely seen from above, but they were exceptionally conspicuous when viewed from a diving helmet while submerged.

Remarks: This species is blenny-like in the rapidity of its movements and general habits and also resembles in this respect, some of the smaller serranids. Our field names of "lavender blenny" or "lavender serranid," given before we had been able to catch an example, are evidence of the appearance of the fish in life.

Specimens Examined: 45, including the types and paratypes, from the localities mentioned above under *Range*.

***Pseudocirrhites* Mowbray, 1927.**

Genotype by monotypy, *Pseudocirrhites pinos* Mowbray, in Breder, *Bull. Bingham Oceanogr. Coll.*, 1 (1), 1927: 48.

This genus is close to the Pacific *Cirrhitichthys*, differing principally in the possession of scales on the nape and interorbital space. In *Cirrhitichthys*, as represented by *C. corallicola* and a Japanese specimen of *C. aureus*, scales are absent on the regions mentioned above, but present in a small subcircular patch between and posterior to the anterior nostrils. I have not checked on other species of *Cirrhitichthys* to determine whether this condition is true of all of the species of the genus.

Considering the geographical isolation of the Atlantic species plus the difference in scalation, *Pseudocirrhites* is maintained as a valid genus, as opposed to synonymizing it with *Cirrhitichthys*, to which it is closely related.

In the original description of *Pseudocirrhites*, Mowbray mentions the following as the principal character of his new genus: "The above new genus is based on the broadly united gill-membranes." This conception of the new genus was probably based on a misstatement in Jordan and Evermann, *Bull. U. S. Nat. Mus.*, 47: 1490, which gained emphasis by being repeated in Jordan and Evermann, *The Shore Fishes of the Hawaiian Islands* (*Bull. U. S. Fish Comm.*, 23 (1), 1905: 446), and in Jordan and Herre's *A Review of the Cirrhitoid Fishes of Japan* (*Proc. U. S. Nat. Mus.*, 33, 1907: 157). This error described the gill-membranes in Cirrhitidae as *separate* and free from the isthmus. Unfortunately this is not true, as the possession of *broadly united* gill-membranes is characteristic of all members of the family that have been examined and is so mentioned in other descriptions beyond those listed here. (See also: Regan, On the Cirrhitoid Percoids, *Ann. Mag. Nat. Hist.*, (8) 7: 259-262).

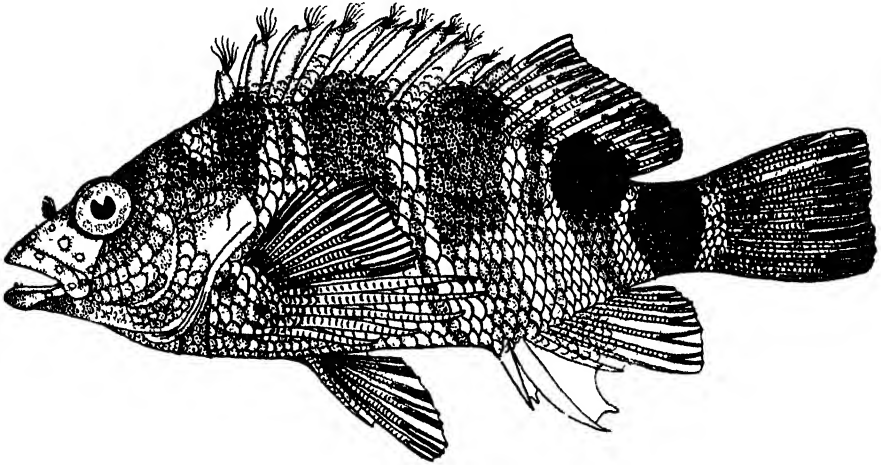
The definition of *Pseudocirrhites* may be rewritten as follows: Cirrhitoid fishes with rather large cycloid scales, approximately 42 rows in a lateral series; 4 to 5 rows of scales on the cheek; nape and interorbital space as far forward as the anterior nostrils fully scaled. Teeth present on the vomer and palatines; jaws with an outer row of small canines inside of which are villiform bands of smaller teeth, a few strong, backwardly-turned canines on center of side of each lower jaw, upper jaw with a few slightly enlarged teeth near the symphysis and toward the posterior end of each jaw. Preopercle serrate. Branchiostegals 6.

***Pseudocirrhites pinos* Mowbray.**

(Text-figure 3).

Proportions in Percentage of the Standard Length, and Counts: Depth 33-38 (2.6-3); head 37 (2.7); eye 9.2-9.6 (3.84-4); snout 11.3-11.7 (3.1-3.3);

maxillary 13-13.4 (2.74-2.86); interorbital space 4.8-5.76 (4.15-6.4); pectoral fin length 36.5-39; pelvic fin length 21.6-25; snout to 1st dorsal fin 36; snout to 2nd dorsal fin 62-64.5; snout to anal fin 70; snout to pectoral fin 34-36; snout to pelvic fin 45-49. 1st dorsal fin height 15.7; 2nd dorsal fin height 18.5-21.5; anal fin height 20.8. *Counts*: dorsal fin X, 11; anal fin III, 6; pectoral fin, 14 rays, the top 1, and lower 5 simple; pelvic fin I, 5; scales: 6 from origin of dorsal fin to lateral line, 42 in a lateral series, 8 from the lateral line to the origin of the anal fin; gill-rakers 6 on upper limb of first arch, 8 to 9 on the lower limb of the first arch.



Text-figure 3.

Pseudocirrhites pnos Mowbray. Drawing of the type, 54 mm. standard length.

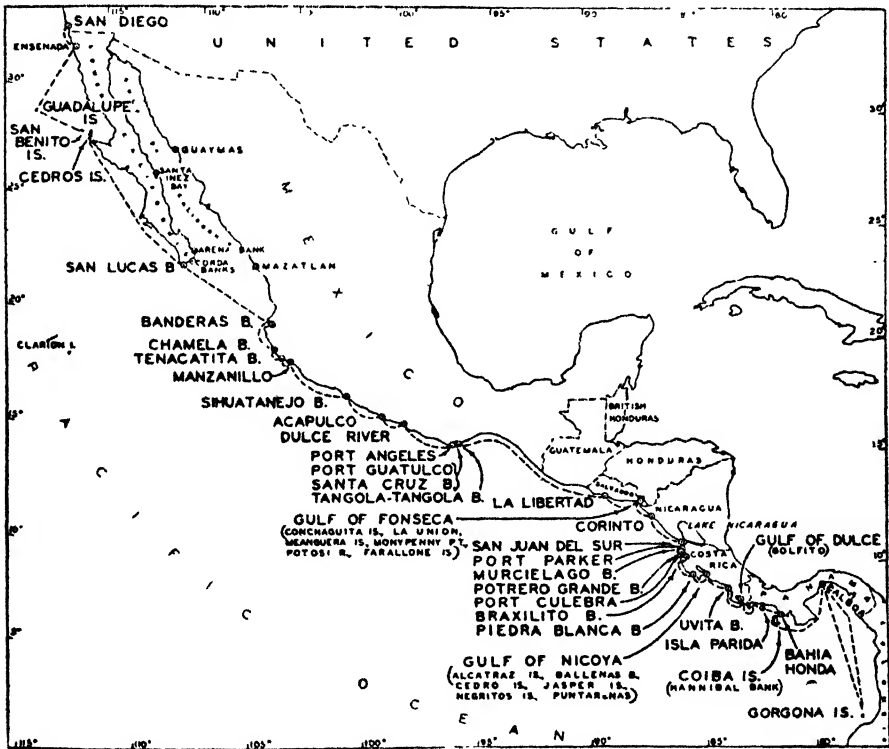
Body oblong, compressed; depth of the caudal peduncle 2.8 in the head. Body and head covered with large cycloid scales, with the exception of the snout and preorbital, and the maxillary and premaxillary; branchiostegal membranes scaled. Lateral line continuous, nearly straight, extending onto the base of the caudal; pores turned obliquely upward. A series of small dermal tentacles on the anterior upper edge of each interspinal membrane of the dorsal fin.

Eye placed high and slightly entering the dorsal profile; interorbital space concave; anterior nostril with a fringed tentacle; preopercle rounded, finely serrate; opercle with a single flat spine; branchiostegal membranes united (accidentally broken during re-examination of the type) and free from the isthmus, covered with small scales; mouth small, placed low; maxillary narrow, about $\frac{3}{4}$ entirely covered by the preorbital; premaxillaries little protractile; villiform teeth in bands in each jaw, on the outer border of which are a band of small canines, 3 or 4 slightly enlarged canines near the symphysis of the upper jaw, a few enlarged teeth at the posterior end of the jaw; a few strong canines on the middle of the sides of the lower jaw; vomer and palatines with small teeth. Caudal fin truncate, its rays about equal in length to the second anal spine, the first spine of the anal fin about 2 in the second, the second spine longest and strongest, the third intermediate in length and strength to the other two; pectoral fin with 14 rays, the uppermost 1, and lowermost 5 simple, the remainder branched; lowermost simple rays considerably longer than the other rays; tip of pectoral extending to the 1st soft ray of the anal fin; pelvic fins with their tips extending to the 1st anal spine.

A 26 mm. fish differs from the type in being less deep, and in having the two upper rays of the pectoral fin simple on the right side, and the upper three simple on the left side.

Coloration: Head and body light brown; three vertical light-colored bands on body, broadest inferiorly, in the center of each band is a narrow brown line; a broad band of dark brown covering the entire caudal peduncle; a brown spot larger than the eye, two-thirds of which is on the body, at the base of the posterior dorsal rays. The bands of the body, both dark and light, extend onto the dorsal fin. Pectoral, ventral and caudal fins pale. Head and nape and dorsal fin with bright red spots.

In a color plate made from life of the 26 mm. fish, the narrow brown lines in the center of the light colored bands are faint; the spot at the base of the soft dorsal and the band on the caudal peduncle are black; the pectoral and anal rays and the basal portions of the upper rays of the caudal fin are reddish.



Text-figure 4.

Map of the Eastern Pacific *Zuca* (1937-1938) Expedition of the Department of Tropical Research of the New York Zoological Society, showing the localities mentioned in the text. The Isle of Pines, Cuba, the type locality of *Pseudocirrhites pinos* Mowbray, is the small island immediately south of the western end of Cuba.

Range: Known from the Isle of Pines, Cuba, and from Saba Bank, 6 miles S. W. of Saba Island, West Indies (17° 35' N., 63° 21' W.)

Local Distribution: The two known specimens of this species were taken in coral, in shallow water (type) and at 25 fathoms.

Study Materials: The type and a specimen taken by the *Arcturus* Oceanographic Expedition on Saba Bank, West Indies, March 15, 1925 (Dept. Trop. Res., N. Y. Zoological Society, No. 5061, color plate A.822.)

References: *Pseudocirrhites pinos*. Mowbray, in Breder, *Bull. Bingham Oceanogr. Coll.* 1 (1), 1927; 48, fig. 23 (Description, color; figure; **type locality**, **Isle of Pines, Cuba**; Type: No. 382, Bingham Oceanogr. Coll., Peabody Museum, Yale University).

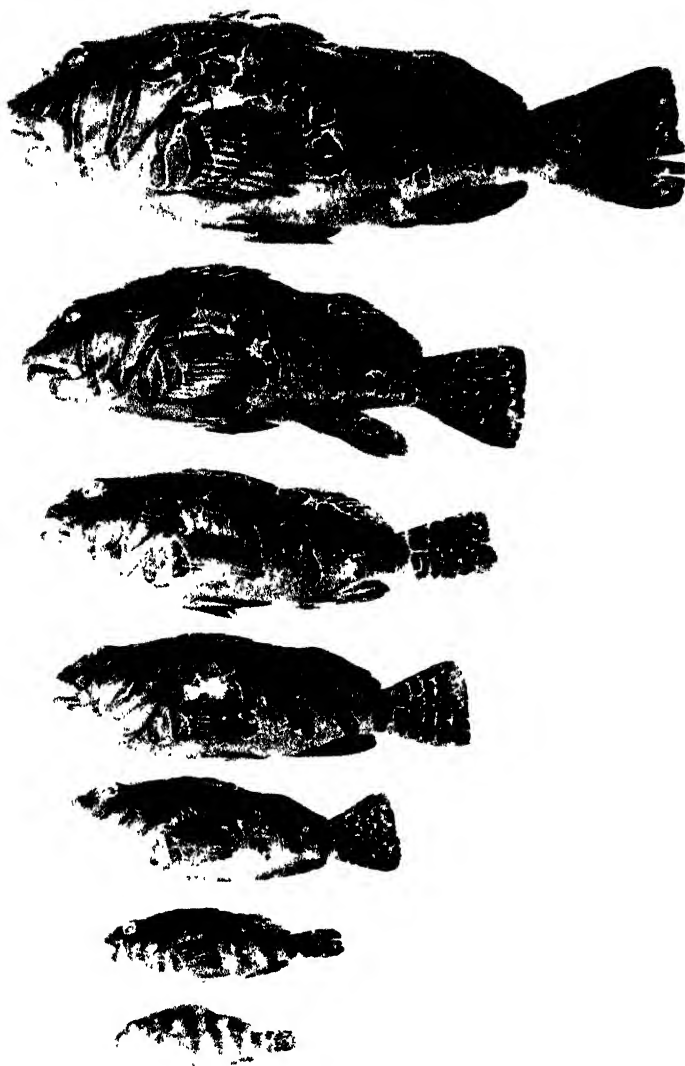
NOTE ON *Cirrhitis rivulatus* (VALENCIENNES).

A 505 mm. fish of this species from the Galápagos Islands (U. S. Nat. Mus., 38,302) examined after this paper was in page proof, has the color bars and bands, especially those of the head, much wider than in smaller specimens and occupying relatively a greater amount of space when compared with the interspaces. The teeth of the upper jaw in this specimen show a few enlarged canines. In the lower jaw the enlarged canines of the middle of the side of each jaw (3 on the right side and 5 on the left) are very large and conspicuous and are wider apart than in smaller fish. Anterior to these there are two or three small canines and posterior to the enlarged group on each side are a group of smaller canines. The villiform teeth in the lower jaw occupy a small patch in the front of each jaw anterior to the large lateral teeth.

EXPLANATION OF THE PLATE.

PLATE I.

Cirrhitis rivulatus (Valenciennes). Seven individuals from Corinto, Nicaragua, 65 mm. to 240 mm. standard length, showing the alteration in pattern correlated with growth and size.



A REVIEW OF THE AMERICAN FISHES OF THE FAMILY CIRRHITIDAE.

6.

Eastern Pacific Expeditions of the New York
Zoological Society. XVIII.

On the Post-embryonic Development of Brachyuran Crabs
of the Genus *Ocypode*.¹

JOCELYN CRANE

*Technical Associate, Department of Tropical
Research, New York Zoological Society.*

(Text-figures 1-8).

[This is the *nineteenth* of a series of papers dealing with the collections of the Eastern Pacific Expeditions of the New York Zoological Society made under the direction of William Beebe. The present paper is concerned principally with specimens taken on the Eastern Pacific *Zaca* (1937-1938) and *Arcturus* Oceanographic (1925) Expeditions. For data on localities, dates, dredges, etc., of these expeditions, refer to *Zoologica*, Vol. VIII, No. 1, pp. 1-45 (*Arcturus*), and *Zoologica*, Vol. XXIII, No. 14, pp. 287-298 (Eastern Pacific *Zaca*).]

CONTENTS.

	Page		Page
I. Introduction	65	V The Megalops of <i>Ocypode</i>	69
II Summary of Important Points	66	A. Material and Methods	69
III Previous Knowledge of Ocypodid Development	66	B. Taxonomy and Identification	70
A. Zoea	66	C. Comparison of <i>Uca</i> and <i>Ocypode</i>	72
B. Megalops	66	D. Generic Characters	72
IV The First Zoea of <i>Ocypode gaudichaudii</i>	67	<i>Diagnosis</i>	72
A. Material and Methods	67	<i>Description</i>	72
B. <i>Diagnosis</i>	67	E. Specific Characters	80
C. <i>Description</i>	67	F. Ecology	81
D. Comparison	69	VI. Bibliography	81

I. INTRODUCTION.

The present paper is the first of a series dealing with the brachyuran crabs of the Eastern Pacific *Zaca* Expedition. It concerns the first zoea of *Ocypode gaudichaudii* and the megalopa of the two Pacific and single Atlantic species of the genus.

Previous reports on the Brachyura of the various Eastern Pacific Expeditions of the New York Zoological Society are the following: Rathbun, 1924, "Brachyuran Crabs Collected by the Williams Galápagos Expedition, 1923" (*Zoologica*, Vol. V, No. 14); Boone, 1927, "Galápagos Brachyura" (*Zoologica*, Vol. VIII, No. 4); Glassell, 1936, "Templeton Crocker Expedition. I. Six New Brachyuran Crabs from the Gulf of California" (*Zoo-*

¹ Contribution No. 591, Department of Tropical Research, New York Zoological Society.

logica, Vol. XXI, No. 17); Crane, 1937, "The Templeton Crocker Expedition. III. Brachygnathous Crabs from the Gulf of California and the West Coast of Lower California" (*Zoologica*, Vol. XXII, No. 3); Crane, 1937, "The Templeton Crocker Expedition. VI. Oxystomatous and Dromiaceous Crabs from the Gulf of California and the West Coast of Lower California" (*Zoologica*, Vol. XXII, No. 7).

The drawings in the present paper are the work of Miss Harriet Bennett.

To Mr. Templeton Crocker I wish to express my appreciation for the opportunity of collecting material on a cruise of his yacht *Zaca*; to Dr. William Beebe, Director of the Department of Tropical Research, for his supervision and advice in the preparation of this paper; and to Dr. Waldo L. Schmitt of the United States National Museum for the loan of specimens, and for his generous permission to dissect an Atlantic megalops and include the results of the study in this report.

II. SUMMARY OF IMPORTANT POINTS.

1. The zoea of a species of *Ocypode* (*O. gaudichaudii* from the eastern Pacific) is described for the first time. It differs from that of the most closely related genus, *Uca*, principally in having lateral spines.

2. The megalopa of both eastern Pacific species of the genus, *O. gaudichaudii* and *O. occidentalis*, are described for the first time. They differ only in small details (such as the number of setae on the last pleopods) from the western Atlantic megalops, *O. albicans*, but are totally distinct from the known megalops of *Uca*.

3. The megalops described by Rathbun (1924, p. 155) as being perhaps referable to *O. gaudichaudii* is shown to belong instead to the genus *Plagusia*, probably to *P. depressa tuberculata*.

4. A probable explanation of the peculiar characteristics of *Ocypode* megalopa is presented: Since a previous investigator (Smith, 1880) found evidence that *Ocypode* moults into the first crab stage in shallow holes on the exposed beach, the megalops must be washed in by the waves. Hence its obesity, its thick, hard cuticle, and its ability, through the development of special grooves, to fold all its appendages tightly against its body, serve as protections against the buffeting of the waves, scraping of the sand, and exposure to the drying effect of air in landing on the beach.

III. PREVIOUS KNOWLEDGE OF OCYPODID DEVELOPMENT.

A. ZOEAE: The zoeal stages of *Ocypode* have been hitherto unknown. Zoeae of a number of other ocypodids, however, have been identified: Those of *Uca pugnator* (Bosc), *U. pugnax* (Smith) and *U. minax* (Le Conte) have been described by Hyman (1920, pp. 485 ff.). Aikawa (1929, pp. 49-51) has described the first zoea of each of the following species: *Macrophthalmus dilatatus* de Haan, *M. japonicus* de Haan, *M. depressus* Ruppell, *Scopimera globosa* de Haan and *Ilyoplax pusillus* (de Haan). The same author (1937, p. 152) gives in tabular form a résumé of the principal characteristics of all the above species.

B. MEGALOPS: Apparently only in the genera *Ocypode* and *Uca* have megalopa been described. In 1817 Say (p. 155 ff.) described as the type of a new genus and species *Monolepis inermis*, a strange creature which he referred to the Macroura near *Porcellana*, although he recognized and was puzzled by its resemblances to the Brachyura. Since the larval stages of crabs were, of course, quite unknown in those days, Say's conclusions were perfectly natural. In this, the first notice of its habits, he says: "Of this interesting animal I found several specimens on the eastern shore of Mary-

land, which had been cast on the beach by the reflux tide. They appeared desirous to protect themselves from the dashing of the surf, and the influence of the sun, by burrowing in the sand, in order to wait the return of the tide; but their efforts had no further effect on the compact sand, than to raise a small portion of the surface, which, by the action of the waves was spread over them so as to be distinguishable from the general surface by a small elevation."

Dana, in 1852 (p. 491) published the only figure of *M. inermis* up to the present time; with it, he described and figured a second species of *Monolepis*, *M. orientalis*, from the Philippines. It was not until 1873 that *Monolepis* was properly identified, when Smith (p. 67) set forth the opinion that *M. inermis* was the young of *M. albicans*; in 1880 (p. 25), he gave evidence, based on watching the actual moulting of a captured specimen taken in Vineyard Sound, that this theory was indubitably correct.

In 1924 Rathbun (p. 155) described a megalops from the Galápagos which she referred, with a question mark, to *O. gaudichaudii*. Boone in 1927 (p. 168) reproduced this description, and a photograph, of the same specimen. As I shall show later (p. 70), this Galápagos megalops should be referred instead to the genus *Plagusia*.

Lebour in 1932 (pp. 18-21) questionably referred two megalopa from the Philippines to this family; at least one of the specimens is certainly an *Ocypode* and the other doubtless belongs in the family if not in that genus (see p. 70).

Hyman (1920, pp. 496-497) has described the megalops of western Atlantic species of *Uca*.

IV. THE FIRST ZOEAE OF *Ocypode gaudichaudii* MILNE EDWARDS & LUCAS.

(Text-figure 1).

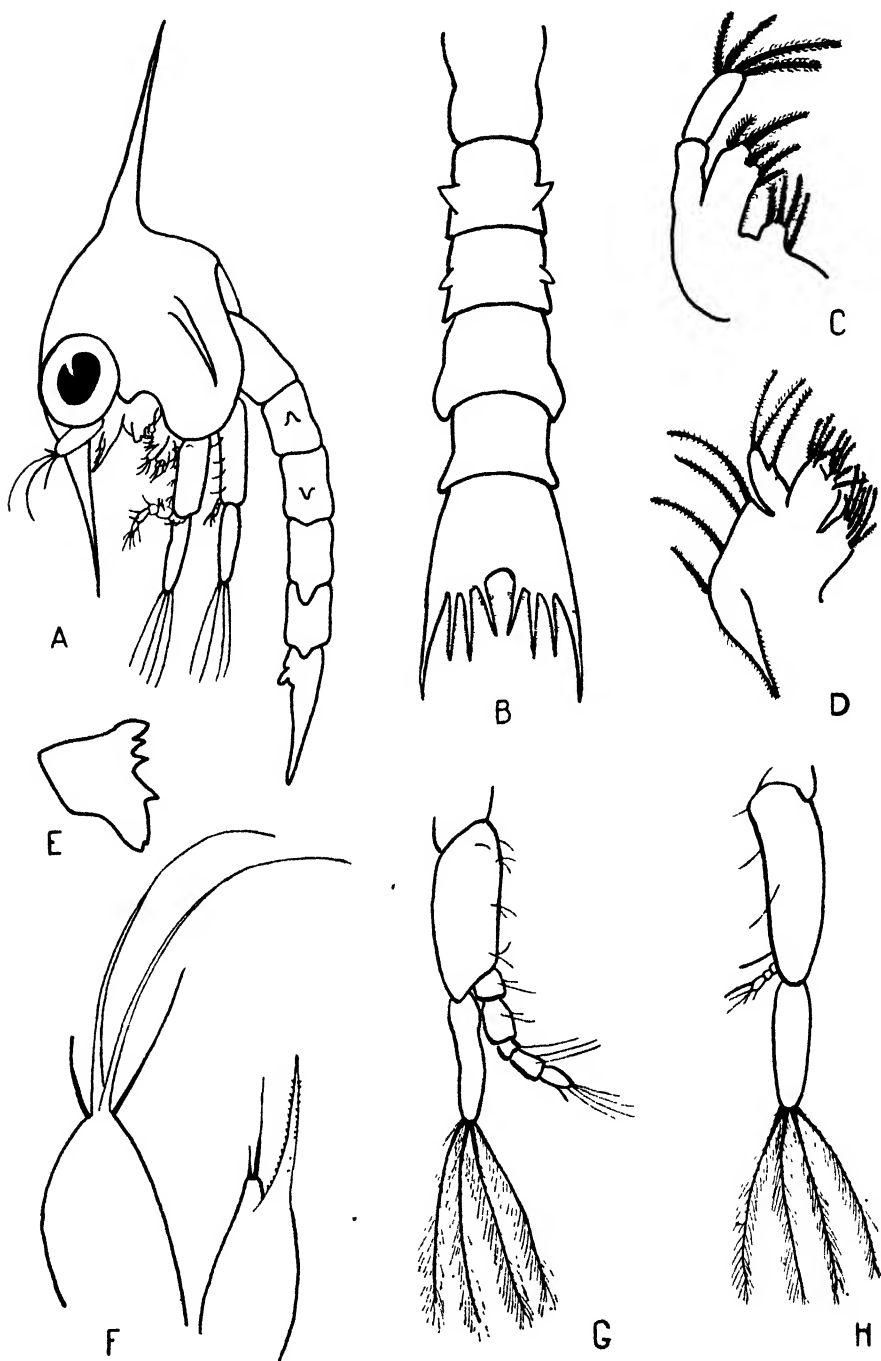
A. MATERIAL AND METHODS: A single ovigerous female was taken during the Eastern Pacific Zaca Expedition, at Bahia Honda, Panama, on March 15, 1938. The crab was kept in an aquarium with shallow water at one end and sand banked up at the other; it was fed bits of shrimp, mussel and fish. Most of its time was spent half submerged in the water. The eggs were well developed at time of capture, dark orange in color; they did not hatch, however, until 11 days later, on March 26. Unfortunately, the prezoaea was not secured. The zoeae lived from 24 to 30 hours—no special attempt having been made to rear them—and were preserved in 70% alcohol. There was no difference between those killed as soon as it was discovered they had hatched, and those that died naturally the next day. They are catalogued in the collections of the Department of Tropical Research, New York Zoological Society, as Nos. 38,798 and 38,818.

In the following description, Aikawa's system of classification of antenna and telson, and his general methods of description, are used, though in amplified form (see Aikawa, 1929, 1933 and 1937).

B. DIAGNOSIS: Dorsal, rostral and lateral spines present. Second antenna B-4 type. Telson B-type; hair formula: endopodite of first maxilla, 4-0; of second maxilla 2-1 (3) with a slight, unequal bifurcation; of second maxilliped, 5-0-0. Spines present on second and third abdominal somites.

C. DESCRIPTION: No primary chromatophores apparent (after 18 months in alcohol); almost all specimens lack even secondary chromatophores, pigment being completely absent except in the eyes.

The following measurements were made from specimens killed and preserved in 70% alcohol: Total length, from front to telson tip, ca. 1.6 mm.; dorsal spine .54 mm.; rostral spine .43 mm.; perpendicular distance between their tips 1.47 mm.; lateral spine .23 mm.; abdomen 1.13 mm. long, .2 mm. wide (at fourth segment); telson .34 mm. long.



Text-figure 1.

Ocypode gaudichaudii: first zoea, total length (preserved in alcohol) 1.6 mm. **A**, lateral view; **B**, abdomen, dorsal view; **C**, first maxilla; **D**, second maxilla; **E**, mandible; **F**, antennule and antenna; **G**, first maxilliped; **H**, second maxilliped.

Postero-lateral region of carapace finely punctate. Dorsal and rostral spines moderately long, the dorsal the longer; dorsal straight, rostral slightly concave anteriorly; lateral spine a little more than half as long as rostral, curved strongly downward.

First antenna with 2 aesthetes and 2 unequal hairs on tip. Second antenna closest to Aikawa's B-4 type (1933, p. 126); much shorter than rostral spine but slightly longer than first antenna excluding terminal hairs; spinous process of peduncle thick with 2 longitudinal rows of serrations extending most of its length, but stopping short of the tip; about 17 serrations in each row; exopodite about one-fourth length of peduncle with a somewhat squared off tip giving rise to 2 unequal terminal hairs, the longer not reaching end of spinous process; flagellum rudimentary or absent.

Coxopodite of first maxilla with 4 hairs, basipodite with 5; endopodite 2-jointed, with 4 hairs on second, none on first segment. Second maxilla with 7 hairs on coxopodite, 9 on basipodite; endopodite with a slight, unequal bifurcation, 2 hairs on larger, distal part, and 1 on smaller, proximal part; scaphognathite with 4 hairs. Propodite of first maxilliped with 2-2-2-2 hairs, of second with 1-1-1-1; endopodite of first maxilliped with 5-2-1-2-2 hairs, of second with 5-0-0.

Abdomen with six segments; a pair of small spines directed anteriorly on second segment, a similar pair directed posteriorly on third segment; fourth segment swollen laterally in posterior portion, the postero-lateral corners projecting backward over succeeding segment, but not actually spinous; corners of fifth segment similarly produced to a lesser extent. Telson B-type (i.e., with a normal, moderate fork, the horns being without spines); fork shallow, slightly more than half length of telson.

D. COMPARISON: The zoea of *Ocypode* differs from that of *Uca* as described by Hyman (1920) as follows: it is larger (at least 1.6 mm. long instead of not more than 1.0 mm.); lateral spines are present; the exopodite of the second antenna is shorter, with 2 unequal terminal hairs, instead of being long, with a short hair arising part way down its length²; the telson is less deeply forked; the endopodite of the second maxilla is slightly but noticeably bifurcated, the smaller, most basal lobe having 1 hair, the larger distal lobe 2 hairs, instead of there being 3 hairs on an unbifurcated tip. Chromatophore differences must be determined from fresh material.

If Aikawa's convincing suggestions as to the evolutionary value of the various characters be accepted, these differences lend support to his remarks on the relationships of the genera of Ocypodidae (1937, pp. 154-5), showing *Ocypode* as a more nearly direct link than *Uca* between the Macrophthalminae and Mictyriinae: While preserving the less specialized form of antenna and telsons found in the Macrophthalminae, it has lateral spines hitherto known in the family only in the Mictyriinae. However, certain knowledge of the relationships of this most interesting family must await a great deal of future study.

V. THE MEGALOPS OF *Ocypode*.

(Text-figures 2-8).

A. MATERIAL AND METHODS: The present study of the megalops is based on the three American species, *O. albicans* Bosc, *O. gaudichaudii* Milne Edwards & Lucas and *O. occidentalis* Stimpson. The first ranges from Rhode Island to Brazil, the second from the Gulf of Fonseca, Salvador, to Chile, and the third from Lower California to Peru.

² This difference may prove to be slighter than it now appears, since Hyman was not certain whether one terminal hair continued the segment of the exopod: "The outer half of the tip of the basal portion bears the distal segment, which is small and cylindrical. From its tip arise two setae, one long, which seems to be a continuation of the segment, and a short, outer one." (Hyman, 1920, p. 491). If it is not a continuation, the antenna would be a B-4 instead of a B-2 type, according to Aikawa's classification (1933, pp. 126-7). There seems no doubt that the present specimens have two, distinct, terminal setae.

Megalopa of both Pacific species (here identified and described for the first time) are included in the collections of the Eastern Pacific Expeditions, as follows:

O. gaudichaudii, 8 specimens:

No. 25,205; Sta. 63 T-1; *Arcturus* Oceanographic Expedition; 20 mi. W. of Mariato Point, Panama (6° 58' N. Lat., 81° 08' W. Long.); night surface haul; May 11, 1925; 2 megalopa; carapace length³ 4.72, 4.86 mm.; breadth 4.58 mm.; total length 5.43, 5.58 mm.

No. 38,112; Sta. 205 L-1; Eastern Pacific *Zaca* Expedition; Potrero Grande Bay, Costa Rica; night light; Jan. 23, 1938; 1 megalops; carapace length 5.58 mm.; breadth 4.72 mm.; total length 9.0 mm.

No. 38,823; Sta. 232 L-1 to L-4; Eastern Pacific *Zaca* Expedition; Gorgona Island, Colombia; night light; March 27-30, 1938; 5 megalopa; carapace lengths 4.86 to 5.72 mm.; breadths 4.3 to 4.86 mm.; total lengths 8.44 to 9.4 mm.

O. occidentalis, 2 specimens:

No. 37,160; Sta. 182 L-1; Eastern Pacific *Zaca* Expedition; Chamela Bay, Mexico; night light; Nov. 17, 1937; 1 megalops; carapace length 4.15 mm.; breadth 4.15 mm.; total length 7.43 mm.

No. 37,547a; Sta. 195 L-1; Eastern Pacific *Zaca* Expedition; Port Guatulco, Mexico; night light; Dec. 3, 1937; 1 megalops; carapace length 5 mm.; breadth 4.29 mm.; total length 7.7 mm.

Three megalopa of *O. albicans* from Woods Hole, Mass., were studied through the kindness of Dr. Waldo L. Schmitt (U. S. N. M. Nos. 10,995 and 11,175; carapace lengths 5.43 to 6.43 mm.; breadths 4.58 to 5.3 mm.; total lengths 8.15 to 9.58 mm.). Although the megalops of this species has long been known (see p. 000), it has never been adequately described and figured. Hence, illustrations of this form are included in the present report. Fortunately, one of these specimens has all the appendages tightly folded against the body, giving the clue for many of the peculiarities of form in the megalops of *Ocypode* (see below).

From a comparison of these three species, the well-marked generic characters of this stage of *Ocypode* become clearly evident. In spite of the similarity of the forms, drawings of the parts of all three are reproduced, as a basis for future work.

B. TAXONOMY AND IDENTIFICATION: As has already been remarked, (p. 67), *Monolepis inermis* has been identified without question as the megalops of *Ocypode albicans*. It is by analogy with this identification that Dana's very similar *M. orientalis* (1852, p. 491) and our own specimens are referred without question to *Ocypode*. Megalopa of the closely related genus *Uca* are, fortunately, very distinct, so that there is no question of confusion (see below, and Hyman, 1920, pp. 496-497 and figs.).

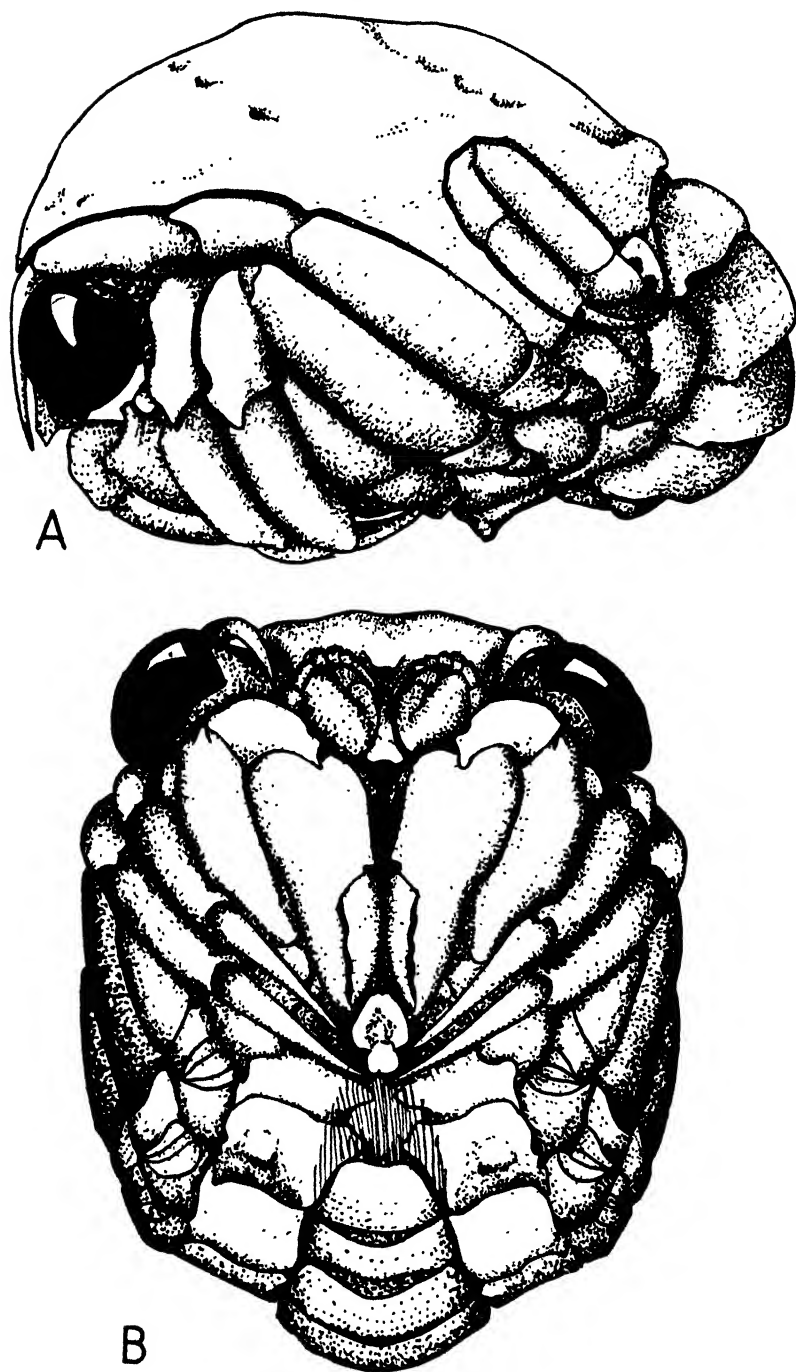
The megalopa questionably referred to *Ocypodidae* by Lebour (1932, pp. 18-21) are undoubtedly members of that family, although the genera cannot at the present time be settled. Her megalops A 1, 12 mm. long, with only seven hairs on the last pleopod and no hairs at the bases of the third and fourth legs, almost certainly does not belong to *Ocypode*; megalops A 2, on the other hand, will very likely prove to be a member of that genus.

A reexamination of the Galápagos megalops identified questionably as *O. gaudichaudii* by Rathbun in 1924, p. 155, shows that this specimen (U.S.N.M. No. 57,735) should be referred instead to the grapsid genus *Plagusia*, probably to *P. depressa tuberculata*, for the following reasons:

1. The spines on the tarsi are characteristic of grapsid, not ocypodid, megalopa.

2. The antennular fossae characteristic of the Plagusiinae are clearly marked, being more deeply incised in a straight dorsal view than the illustration indicates (*ibid.*, pl. VII, p. 154).

³ Measured in median line.



Text-figure 2.

Ocypode albicans, megalops, showing position of appendages when folded against body. **A**, lateral view; **B**, ventral view. (From U. S. National Museum specimen No. 10,995; length of carapace in median line, 6.43 mm.).

3. The form of the maxillipeds is more similar to that of the adults of *Plagusia* than of *Ocypode*.

4. There are no hairs between the bases of the third and fourth legs. These are clearly apparent in true *Ocypode* megalopa.

5. Minor points such as the arrangement of hairs on the manus of the cheliped and on the carapace are typical of *Plagusia*, and especially of *P. depressa tuberculata*.

6. Finally, comparison with Aikawa's description and figures of *Plagusia dentipes* (1937, p. 136, fig. 36), and with *Percnon* megalopa in our own collections, show the close relationship in many similarities, while the thick cuticle, the exaggerated body depth and the sternal sculpturing which are so characteristic of true *Ocypode* are lacking.

The Pacific megalopa of the present collections, listed above, are divided without hesitation into the two Pacific species, *O. gaudichaudii* and *O. occidentalis*, since both specimens of the latter form were taken well north of the northern boundary of *O. gaudichaudii*'s range, and exhibit distinct specific characters in the number of setae on the last pleopods and pattern of the sternal sculpture.

C. COMPARISON OF *Uca* AND *Ocypode*: The megalopa of *Ocypode* and *Uca* have in common the following characters, which seem to be of the most diagnostic value in determining families (see especially Lebour, 1928, pp. 488-491): Rostrum pointed, sharply bent, with a single median spine; no spines on carapace; 3 curved "feelers" on dactyls of fifth legs; more than 6 hairs on exopodites of last pleopods; hooks on basal segments of legs rudimentary or absent. In addition they have small, 10-11-segmented antennae; small chelipeds; external maxillipeds and other mouthparts of a general shape typical of adult Ocypodinae; and a tuft of hairs between the bases of the third and fourth legs, also as in the adults. There are no spines on the dactyls of the second, third and fourth legs.

Although present material is inadequate for a complete comparison, megalopa of these two genera may be distinguished by the following key. The characteristics of *Uca*, as given in the above paragraph and in the key, are taken from Hyman (1920, pp. 496-497).

A. More than 20 hairs on exopodite of last pleopod; anterior part of sternum conspicuously sculptured; no distinct bulge on inner margin of merus of third maxilliped; cuticle thick and hard; body excessively obese, almost cylindrical; carapace grooved for reception of appendages when folded *Ocypode*

AA. Less than 15 hairs on exopodite of last pleopod; anterior part of sternum smooth; a distinct bulge on inner margin of merus of third maxilliped; cuticle not noticeably thick and hard; body not unusually obese, but instead flattened dorso-ventrally as is usual in megalopa; carapace not grooved for reception of appendages when folded *Uca*

D. GENERIC CHARACTERS: The following description of *Ocypode* is based only on the three American species.

Diagnosis. Megalops large (total length up to 9.4 mm.), extremely obese⁴, heavy, deeply pigmented, with thick, hard cuticle; rostrum small, vertical; sternum sculptured anteriorly, the pattern varying with the species; deeply grooved posteriorly for reception of the short abdomen; a prominent transverse, truncate, suborbital projection; chelipeds small; three curved "feelers" on tip of fifth leg; hooks on ischium of legs rudimentary or absent; a tuft of hairs present between bases of third and fourth legs; no spines on dactyls of walking legs; 22 to 28 setae on last pleopod.

Description. General color yellowish to dark brown with individual black chromatophores large and numerous or small and sparse, varying with the individual; carapace large, rounded dorsally, almost dome-shaped,

⁴ Maximum body depth almost or quite equalling carapace width.

straight in front with small, three-pointed rostrum, the central spine longest, triangular, sharply bent, vertical in large specimens; two frontal eminences; frontal, gastric, cardiac and intestinal regions sometimes with pores, variously numbered and arranged, present or absent in individuals of the same species, possibly connected with moulting; a groove in the cardiac region, curving posteriorly, and a corresponding one in the intestinal curving anteriorly; both grooves varying slightly with the individual within the species; in the posterolateral region is a depression for the reception of the folded fifth leg.

Lateral region of carapace very deep, vertical, provided with shallow grooves for reception of the bent second, third and fourth legs. A prominent, rounded, horn-like projection extends sidewise from the suborbital region. Anterior sternal region sculptured with a prominent central knob, and various adjacent smaller projections, depressions and excavations, the pattern depending upon the species, and varying slightly with the individual; into and around this area fit the folded dactyls of the chelipeds and of the second and third legs. Sternal segments well marked, a projection on the one at the base of the second leg. Sternal groove deeply excavated for reception of the short, thick abdomen.

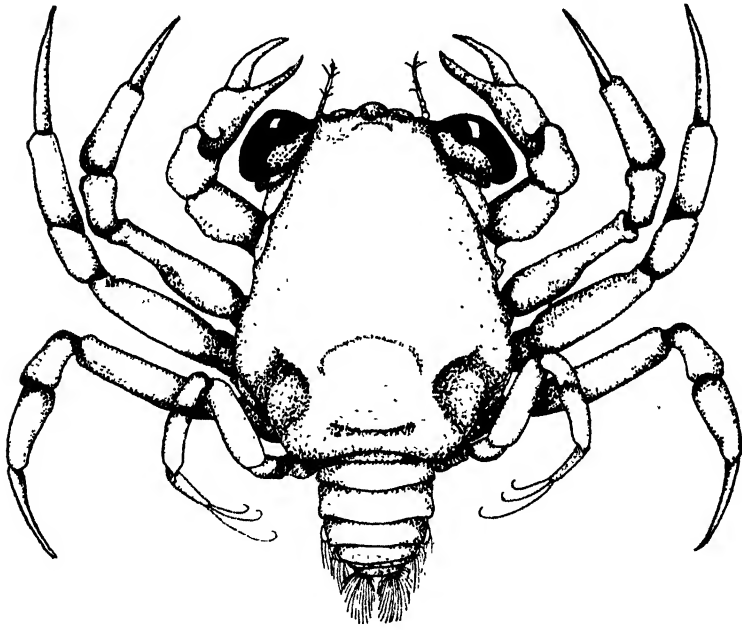
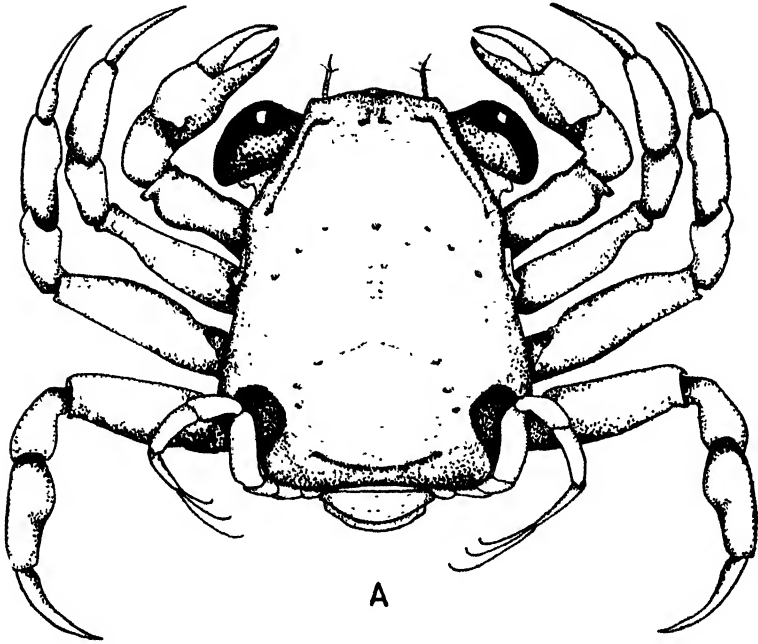
Antennule (Text-fig. 7 A-C) almost concealed, with a large, swollen basal segment containing a statocyst already well developed, and a five-jointed terminal process composed of the second to the sixth segments. A fringe of hairs makes a continuous line across the lower part of the basal segment and the upper part of the second, which arises from the inner, lower portion of the base. Anteriorly the base gives rise to two hairs. From the third segment arises a small, single-jointed external flagellum tipped with three or four hairs. The fourth, fifth and sixth segments bear about 6 to 10 long, sensory hairs each; in addition the sixth segment is tipped distally with a single stout hair. The antennule differs from that of the megalops of *Uca* (Hyman, 1920, p. 496, fig. 26) chiefly in the presence of an external flagellum, of three, not two segments in the terminal process, and of a fringe of hairs across the basal and second segments. In the adult *Ocypode* the basal segment is proportionally much larger, the external flagellum has two, not one, joints, and the terminal process is degenerate, almost lacking hairs and with only one segment apparent.

Antenna (Text-fig. 7 D-F) very short, similar to antenna of *Uca* in segmentation (*ibid.*, fig. 34), composed of three basal segments and a seven-jointed flagellum of which the fifth segment is longest (later to be divided into two, giving the 11 joints of the adult); a few sensory hairs at base of penultimate segment and a single distal hair; one to several hairs usually present on first two basal segments and third and fourth segments of flagellum. Because of the fragility of the antenna, an exact hair count and comparison of the three species studied is not possible with the present material.

Eyes moderately large, little projecting. Mandible (Text-fig. 7 G-I) similar to that of adult, with the cutting edge worn variously by use; palp three-jointed, as in adult and in *Uca*. Maxillae (Text-fig. 7 J, K) and maxillipeds (Text-fig. 8) similar to those of adult and of *Uca* (*ibid.*, figs. 51, 60, 68, 70, 74). First maxillae with very strong bristles on basal lobes, and a two-jointed palp. Epipodites large in first and third maxillipeds, moderate in second. No prominent bulge on inner edge of ischium of third maxillipeds, as there is in *Uca*, in both megalops and adult.

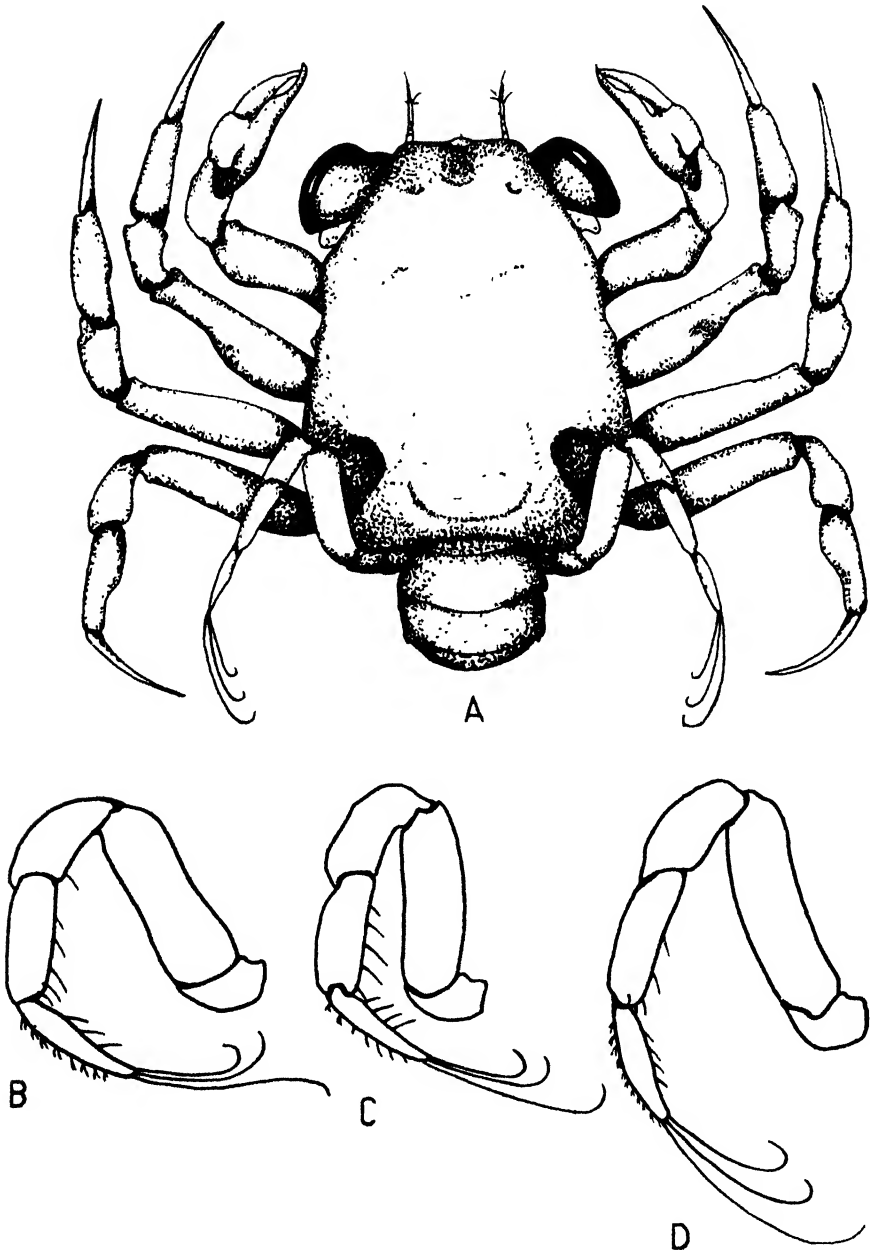
Chelipeds small, being short and only moderately broad and heavy.

Second, third and fourth legs small, fifth leg very small. All have various grooves, excavations and bulges on the segments which enable them to fit with extreme precision and tightness against the body and each other when folded: The chelipeds are held against the pterygostomium region, the second and third legs against the sides, each other and the sternum,



Text-figure 3.

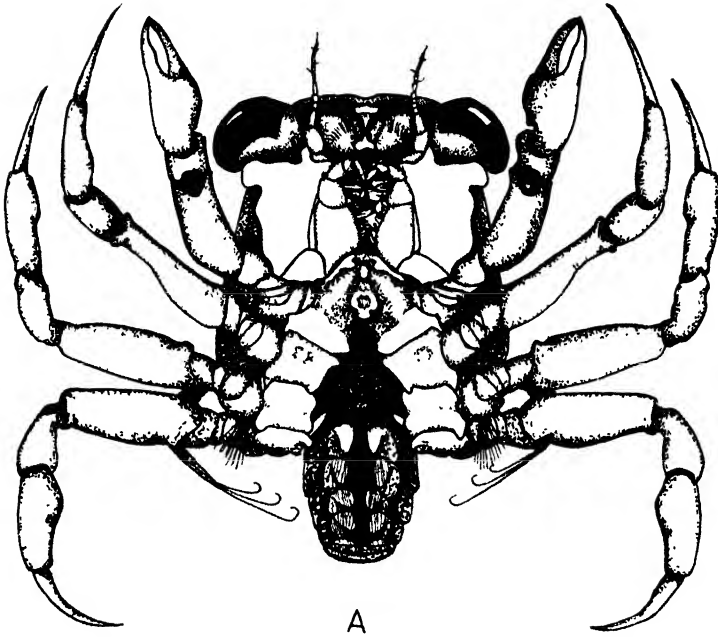
A. *Ocypode albicans*; **B.** *Ocypode occidentalis*. Dorsal view of megalopa, total lengths 8.15 and 7.43 mm. respectively. Short hairs on legs omitted.



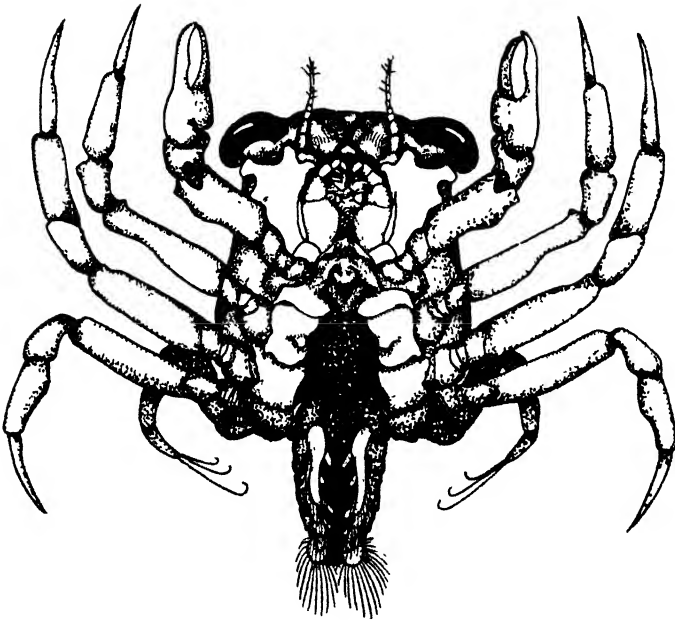
Text-figure 4.

A. *Ocypode gaudichaudii*. Dorsal view of megalops, total length 8.6 mm. Short hairs on legs omitted. **B, C, D.** fifth legs of megalops of *O. albicans*, *O. occidentalis* and *O. gaudichaudii*, respectively, all drawn to same scale.

the fourth leg, which is the longest, straight forward with the dactyls hooking over the eye-stalk, and the tiny fifth legs exactly fitting into the posterolateral grooves. The few interstices left on the ventral surface of



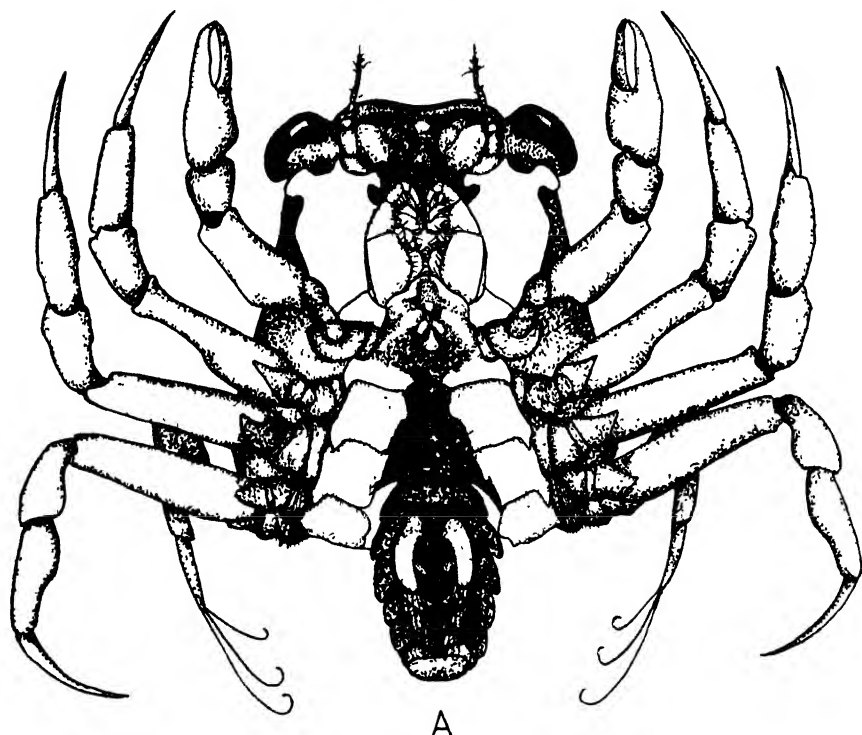
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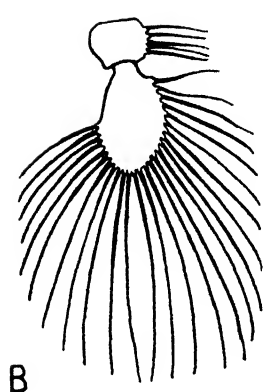
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Text-figure 5.

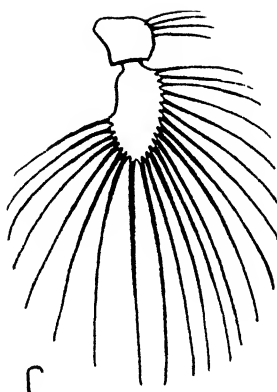
A, *Ocypode albicans*; **B**, *O. occidentalis*. Ventral views of megalopa in Text-fig. Short hairs on legs omitted.



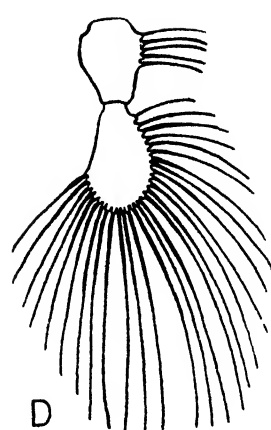
A



B



C

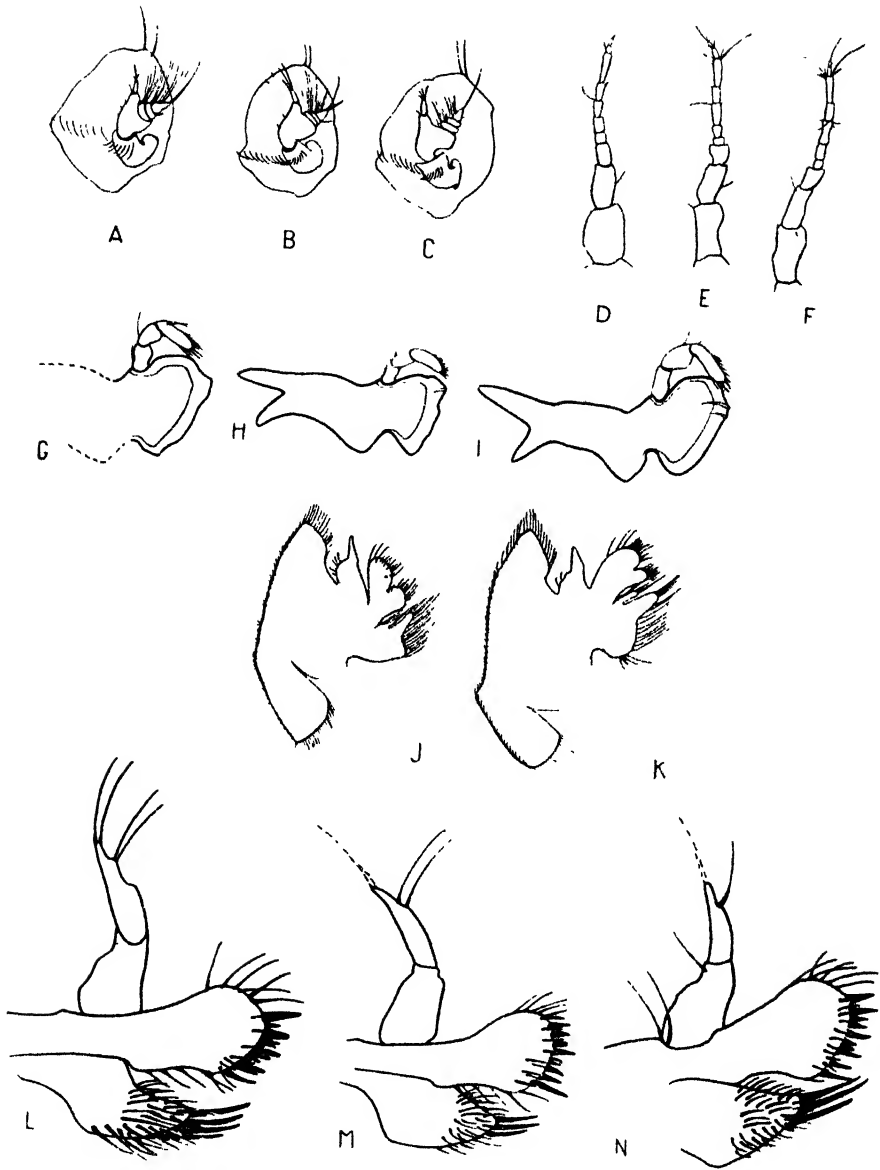


D

Text-figure 6.

A. *Ocypode gaudichaudii*. Ventral view of megalops in Text-fig. 4. Short hairs on legs omitted. **B, C, D.** exopodites of last pleopods of *O. albicans*, *O. occidentalis* and *O. gaudichaudii*, respectively, all drawn to same scale.

the megalops by the folded legs are exactly filled with the suborbital, epistomal and sternal projections. Hooks on ischia or meri rudimentary or absent (except in chelipeds of a Philippine specimen: see Lebour, 1934, p. 20, fig. 18).

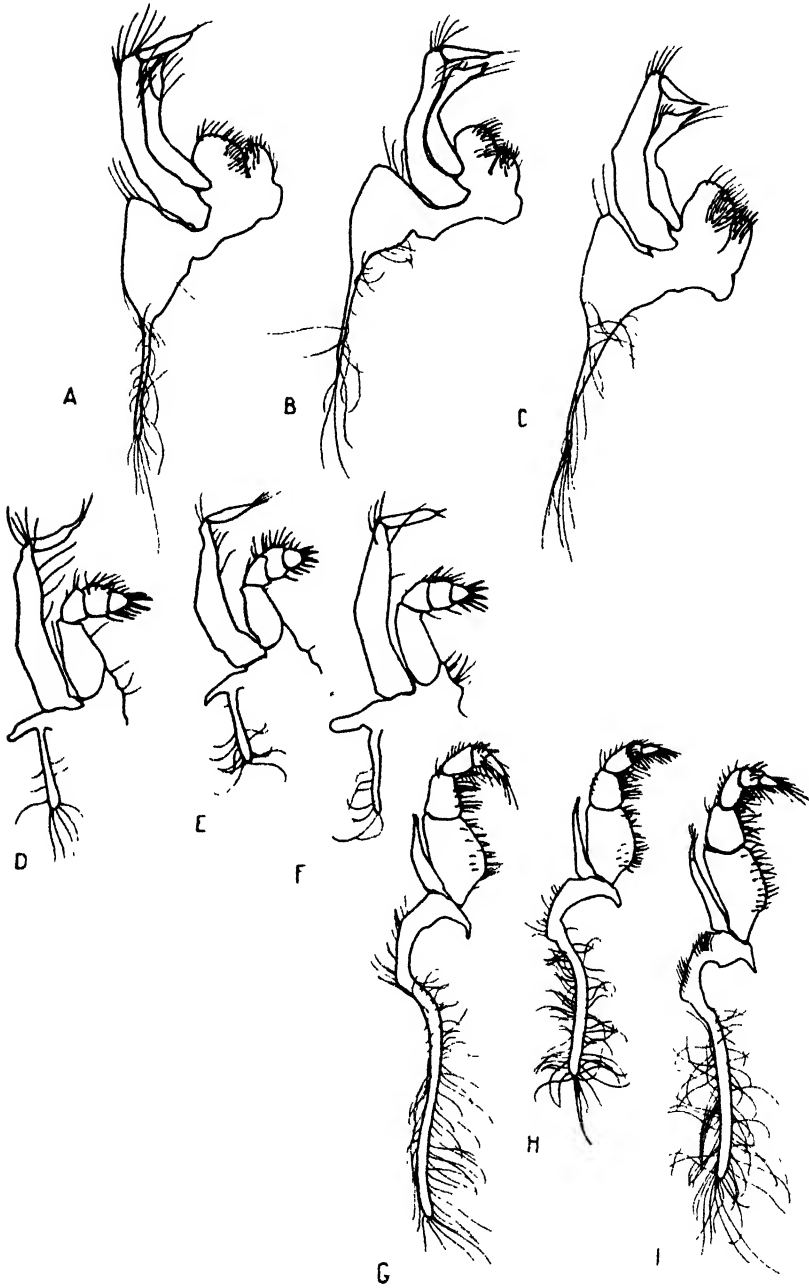


Text-figure 7.

Appendages of megalopa of *Ocypode*. **A, B, C**, antennule of *O. albicans*, *O. occidentalis* and *O. gaudichaudii*, respectively; **D, E, F**, antenna of *O. albicans*, *O. occidentalis* and *O. gaudichaudii*, respectively; **G, H, I**, mandible of *O. albicans*, *O. occidentalis* and *O. gaudichaudii*, respectively; **J, K**, second maxilla of *O. albicans*, and *O. gaudichaudii*, respectively; **L, M, N**, first maxilla of *O. albicans*, *O. occidentalis* and *O. gaudichaudii*, respectively. The corresponding parts of the three species are, in each group of drawings, drawn to the same scale.

A tuft of hairs present, as in the adult, between the bases of the third and fourth legs.

No spines on dactyls of second, third and fourth legs.



Text-figure 8.

Maxillipeds of megalopa of *Ocypode*. **A, B, C**, first maxilliped of *O. albicans*, *O. occidentalis* and *O. gaudichaudii*, respectively; **D, E, F**, second maxilliped of *O. albicans*, *O. occidentalis* and *O. gaudichaudii*, respectively; **G, H, I**, third maxilliped of *O. albicans*, *O. occidentalis* and *O. gaudichaudii*, respectively. All drawn to same scale. Number of hairs on epipodites approximate.

Fifth legs (Text-fig. 4 B-d) with three curved feelers on last segment. Last pleopods with 22 to 28 setae (Text-fig. 6 B-D). Telson rounded.

From the present material it is impossible to tell whether there are one or two megalopal stages, since none has been reared. Smaller examples within the species differ considerably from larger in minor details of carapace modeling, as well as in size, and it seems likely that unlike *Uca* (Hyman, 1920, pp. 496-497) there are two, not one. If this is so, then both specimens of *O. occidentalis* are doubtless in the first megalops stage.

E. SPECIFIC CHARACTERS: Although, during this period, the three American species are so similar, there are two characters by which the forms may be easily differentiated: the number of setae on the exopodites of the last pleopods and the form of sculpturing on the anterior part of the sternum. These differences are best shown as follows:

O. occidentalis:

Anterior part of sternum as in fig.;
22 to 23 setae on last pleopods.



O. albicans:

Anterior part of sternum as in fig.;
26 to 28 setae on last pleopods.



O. gaudichaudii:

Anterior part of sternum as in fig.;
27 to 28 setae on last pleopods.



Minor differences are shown in the illustrations. The mouthparts are larger and hairier in *gaudichaudii* than in the other two species, as in the adults.

F. ECOLOGY: The outstanding characteristics of the megalops of *Ocypode* are its obesity, the thickness of its cuticle and its provision for folding the appendages tightly against the body. These peculiarities are explained when the habits of the megalops are taken into account. The adult lives on beaches which are usually fully exposed to a heavy surf. The megalops described by Say (1817, the type of *Monolepis inermis*) and some of the specimens taken subsequently at Woods Hole by Smith (1873 and 1880) were taken on the beach, sometimes in the act of digging a rudimentary hole, apparently preparatory to moulting, or at least as protection from the waves. Thus it seems almost certain that the moult to the first crab stage takes place on the beach. If this is so, all the megalopal peculiarities named above are easily explained by the following theory: The thickness of the cuticle, the rotundity of form and the complicated arrangements for the folding of the appendages are all protections against the pounding of the surf and the scraping of sand in the shallows, as the megalops literally rides to shore on the crest of a wave. Were it fragile, with the appendages outspread, it would obviously lose most of the limbs and be battered in landing; also, it would run the risk of having the breathing apparatus clogged by the sand swirling at the edge of the tide. Afterwards, when the megalops has been left stranded, the thick cuticle helps conserve vital body moisture, and, if the megalops does actually, under normal circumstances, dig at this time, such hardness is obviously essential.

All of the specimens in the present collection were taken at night lights, usually just off shore; one, however, was captured twenty miles from the nearest land; in all probability such megalopa never reach a beach, and, of course, countless others must be washed up on rocky or otherwise uninhabitable coasts. Still others, as with New England examples of *O. albicans*, are carried by currents far out of their range, where the climate is so unsuitable that ultimate survival is impossible.

It will be interesting to learn whether other beach-dwelling ocypodids have similar adaptations, when their megalopa are discovered. Species of *Uca* which live in protected marshes and lagoons are not exposed to the same dangers in landing at the end of the megalopal stage; the lack of these specializations in Hyman's (*ibid.*) examples of *Uca* are apparent.

The stomachs of five megalopa (one of *occidentalis*, four of *gaudichaudii*) were examined and found to be completely empty except, in one case, for the remains of two minute crustaceans, apparently copepods.

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7.

New Species of British Guiana Heterocera.¹

W. SCHAUS

United States National Museum,
Washington, D. C.

INTRODUCTION.

During the eight years of occupancy, by the Department of Tropical Research, of the New York Zoological Society's Station at Kartabo, British Guiana, extensive collections of insects were made. These were all taken in the quarter-mile area under intensive study—what may be called the Guiana Jungle-zone. The first collection of Lepidoptera was reported on by Dr. H. G. Dyer, in *Zoologica*, Vol. I, No. 4, 1909, pp. 125-138, where 5 new genera and 24 new species were described.

Dr. W. Schaus has recently examined other Kartabo collections and has written the following paper, with descriptions of 14 new species of Heterocera. The types are all deposited in the collection of the United States National Museum at Washington, D. C.—William Beebe.

New species described in this paper are the following:

Noctuidae: *Pseudbarydia elipha*, *Argidia alonia*, *Argidia azania*.

Lasiocampidae: *Euglyphis marbodia*, *Tolyte loisa*.

Saturniidae: *Hylesia derica*.

Dalceridae: *Ca restricta*.

Limacodidae: *Venadicadia cetiona*.

Geometridae: *Macaria barticaria*, *Microgonia hildonia*, *Dithadama ? domarita*.

Lithosiinae: *Leucotmenis kaletura*, *Prepiella decoloria*.

Hepialidae: *Phassus guianensis*.

NOCTUIDAE.

***Pseudbarydia elipha* sp. nov.**

Female: Palpi grayish-white above, black underneath; head white; collar dark gray; thorax grayish-white; abdomen above citrine drab with grayish-white segmental lines faintly indicated toward angle segment, underneath whitish with darker lines. Fore wing: some whitish-gray mottling at base of inner margin; antemedial line black, wavily inbent from costa, and excurved on inner margin; medial space dark olive buff limited by a black and white lunular line, almost vertical from costa; a postmedial black line inbent on costa then outbent, lunular, and incurved beyond cell to inner margin, inwardly edged with white; the space toward costa has the lunular line double, also edged with white and containing some small brown spots; a curved double black line on discocellular; terminal space brownish-olive with some white scaling subterminally above inner margin; apex brown

¹ Contribution No. 592, Department of Tropical Research, New York Zoological Society

edged below with broad black scaling and an incurved series of thick black spots; termen with a double black line alternately broken on interspaces; cilia whitish. Hind wing glossy deep colonial buff with purplish-brown suffusions along inner margin; a short black streak across end of cell; a dark brown subterminal fascia widest at costa and diminishing to anal angle; termen with small white spots and white cilia. Wings below purplish-gray, the veins finely darker; short dark streaks at end of cells; a subterminal fuscous fascia crossed by black streaks; termen pinkish-gray with a terminal wavy black line.

Expanse: 55 mm.

Habitat: Kartabo, British Guiana.

Type: Cat. No. 34737, U. S. N. M.

***Argidia alonia* sp. nov.**

Male: Palpus and throat coral red, the palpi inwardly white; head and collar dull gray, the latter with a black medial line; thorax mostly dull purplish with black lines; abdomen dorsally vinaceous fawn, laterally and underneath pale rhodonite pink. Fore wing vinaceous fawn, the base of costa darkly shaded, the base of inner margin paler, both limited by an antemedial dentate black and white line followed by a bluish-gray, black-edged round spot; a medial short black line across costal margin; at end of cell a broken, finely edged black, round spot, containing some bluish-green scales which are continued to a larger more outward spot somewhat kidney-shaped, bluish-violet edged by a fine white line; costal edge to apex yellowish, interrupted postmedially by some black scales, below it a fine white-edged black line straight from vein to inner margin, termen partly avel-laneous with a series from apex of small white lunular spots. Hind wing dull purplish-lilac, the costal margin pale bluish-white; below end of cell an irregular black-edged spot containing white scales and four black points; a medial series of small black and white lunular and similar postmedial spots on interspaces; along termen bluish-white spots, the cilia black. Wings below cream buff, the markings fine, dark brown. Fore wing: a point in cell, a faint inangled medial line, an incurved line on discocellular; an incurved postmedial line fine and pinkish to end of cell, then darker and inbent to inner margin; from it above vein 6 a line to termen, the latter Hay's lilac with fine dark edges. Hind wing: a faint antemedial line and a more intense postmedial straight line, the termen as on fore wing.

The species is near *Argidia hilaris* Walker.

Expanse: 43 mm.

Habitat: Kartabo, British Guiana.

Type: Cat. No. 34738, U. S. N. M.

***Argidia azania* sp. nov.**

Female: Palpus black with some grayish scales at tip; head buckthorn brown; thorax wood brown, the patagia with tufts of cinnamon hairs; abdomen dorsally at base dark olive buff, becoming cinnamon buff at anal segment; a lateral black line; underneath, dull tawny olive; hind tibiae with white spots.

Fore wing: basal half yellow ocher with pinkish suffusions; an antemedial lunular line followed in cell by a small round white spot circled with a black line; two smaller similar spots medially at end of cell and well separated; a broad vinaceous rufous fascia postmedially from costa at apex to inner margin, crossed by a fine black and white line, excurved below costa, then inbent, straight to inner margin followed by a subterminal series of small black spots preceded by white scales above inner margin; a terminal

fine black line partly cut by veins; cilia red. Hind wing dull purplish-ocher at base; a white point in cell; a narrow fascia, vinaceous rufous medially, limited by a straight black and white line, followed by clusters of black and white scales, then by an irregular series of small black spots; termen dull red. The veins with long black lines. Fore wing below cinnamon, somewhat darker on termen; a black point in cell and a small black and white spot on discocellular; a fine postmedial black line outwardly edged with white; costal edge dark purplish; a terminal black line. Hind wing below slightly paler, the inner margin grayish; a fine white and black line on discocellular and a fine dark medial line.

Expanse: 62 mm.

Habitat: Kartabo, British Guiana.

Type: Cat. No. 34750, U. S. N. M.; Department of Tropical Research No. 2084.

LASIOCAMPIDAE.

Euglyphis marbodia sp. nov.

Female: Head wood brown, also the thorax; abdomen above light cinnamon drab with dark transverse lines edged with gray and silver scales, underneath cinnamon drab. Fore wing grayish-pink; a black line above inner margin connected with a fine black outcurved medial line touching a dentate black spot at end of cell; an outangled fine black postmedial line inbent to spot at end of cell, then somewhat wavy to inner margin; a subterminal dark line outcurved from costa, then sinuous to inner margin, inwardly bordered with the ground color; termen wood brown. Hind wing mostly wood brown; a medial wavy black line, outwardly edged with white at costa; a fine wavy subterminal black line; termen narrowly wood brown. Underside of wings buffy brown without any markings.

Expanse: 60 mm.

Habitat: Kartabo, British Guiana.

Type: Cat. No. 34739, U. S. N. M.

Tolype loisa sp. nov.

Male: Antennae light vinaceous fawn. Head, collar and thorax white, the patagia with pinkish-white hairs. Abdomen above pinkish-white with grayish mottling, underneath pallid gray. Fore wing partly bluish-white; costal margin light cinnamon drab slightly paler toward apex; a double fine antemedial line across cell, angled close below cell, the veins crossing the medial space well defined; a fine line across end of cell; a double dark, sinuous, postmedial line followed subterminally by three fuscous spots and a dark spot at tornus; cilia white; the inner margin with some long, fine black and cinnamon hairs. Hind wing very pale vinaceous lilac, the termen faintly darker, the cilia white. Wings underneath whiter, the fore wing with indications of the dark costa and the subterminal spots.

Expanse: 20 mm.

Habitat: Kartabo, British Guiana.

Type: Cat. No. 34740, U. S. N. M.

SATURNIIDAE.

Hylesia derica sp. nov.

Female: Head and thorax chaetura drab. Abdomen above, benzo brown with light brownish-drab transverse lines, underneath chaetura drab. Fore

wing dark purple drab; costa medially pale brownish drab, and a similar transverse fascia, within it a dark streak across end of cell; a similar subterminal wavy fascia. Hind wing light vinaceous drab, the veins defined by fine dark lines; indications of a broad postmedial fascia, the termen narrowly dark purple drab. Wings below light purple drab, the hind wing with a broad postmedial fascia cut by fine dark lines on veins.

Expanse: 60 mm.

Habitat: Kartabo, British Guiana.

Type: Cat. No. 34741, U. S. N. M.

DALCERIDAE.

***Ca restricta* sp. nov.**

Male: Antennae silvery olivaceous yellow; palpi yellow; thorax and base of abdomen silvery white. Fore wing pale grayish-vinaceous; costal margin silvery white; faint darker shading at tornus; a black point at end of cell; termen with short black streaks between the veins; cilia and hind wing silvery white; a very faint terminal line; wings below silvery white.

Expanse: 21 mm.

Habitat: Kartabo, British Guiana.

Type: Cat. No. 34742, U. S. N. M.

LIMACODIDAE.

***Venadicadia cefiona* sp. nov.**

Male: Palpi reddish brown; vertex with white scales; collar black; thorax reddish with a pinkish-white lateral line; metathorax with roseate tufts; abdomen above reddish-brown with black segmental lines, underneath silvery white with dark gray segmental lines. Fore wing: costa and two longitudinal veins, also the inner margin, broadly grayish-red; the three interspaces on anterior half of wing dark purple brown, all limited by an outbent pinkish line from costa to termen above vein 2; apex narrowly white, the space below it postmedially with a curved white line from costa and some dark brown shading between the veins; a subterminal series of small black spots on interspaces; termen narrowly reddish, the cilia roseate. Hind wing mostly black with reddish suffusions on interspaces according to light; cilia white or dark also according to light. Fore wing below fuscous brown, the costal edge narrowly pinkish-white, the inner margin broadly white toward outer margin, the termen pinkish on interspaces, the cilia narrowly brownish. Hind wing below dull grayish thickly irrorated with darker scales, the costa with some white shading, the cilia white. All colors variable according to light.

Expanse: 20 mm.

Habitat: Kartabo, British Guiana.

Type: Cat. No. 34743, U. S. N. M.

GEOMETRIDAE.

***Macaria barticaria* sp. nov.**

Male: Antennae dark brown; palpi and frons roseate; vertex gray; collar pale pinkish; thorax white; abdomen white with some black points. Fore wing mostly white irrorated with short black and reddish streaks; paired black streaks on base of costa; a fine black antemedial line, slightly curved, more intense on inner margin; a fine wavy reddish line medially

starting from a red and black streak on costa; a postmedial straight black line outwardly edged with dark violet from costa to anal angle; termen whitish with minute black points, and subterminal dark spots, not reaching apex; a double black terminal line. Hind wing: basal half white with a fine wavy antemedial pinkish line, and a black point beyond cell; outer half of wing light purplish-vinaceous; a terminal black line. Wings underneath white, the markings of upper side more intense, the lines broader, mostly brick red, the termen of hind wing harmonizing with the fore wing.

Expanse: 35 mm.

Habitat: Kartabo, British Guiana.

Type: Cat. No. 34744, U. S. N. M.

***Microgonia hildonia* sp. nov.**

Male: Palpus below roseate; head gray; the thorax pinkish-white; abdomen dorsally with some black scales at base, otherwise pale pinkish-white with fine darker striae and an antemedial fine reddish line followed by a black point; a dark spot on costa at apex, from it a dark angled line continued as a fine reddish line to inner margin postmedially; termen yellowish-white with fine darker streaks and some faint brownish spots subterminally. Hind wing: the costal margin white, the wing otherwise vinaceous with numerous darker streaks; a black point at cell before a reddish antemedial line; some postmedial faint dark spots and striae; a fine, dark, terminal line. Wings below white with scattered dark scales and black points at cells; the termen broadly yellow ocher, not reaching anal angle on hind wing.

Expanse: 30 mm.

Habitat: Kartabo, British Guiana.

Type: Cat. No. 34745, U. S. N. M.

***Dithadama ? domarita* sp. nov.**

Female: Palpi reddish; vertex light gray, thorax gray, laterally black; abdomen above partly roseate with narrow and broad fuscous lines; anal segment grayish-white, underneath the same with fine dark segmental lines. Fore wing largely purplish-gray; costal edge black not reaching apex with a whitish gray streak below it to subterminal line; the basal color crossed by a medial wavy sinuous dark brown line from close below costa to inner margin, followed by a dark shade parallel to it; a subterminal wavy dark brown line from costa slightly outbent, well incurved from vein 3 to inner margin; termen lilacine gray crossed by dark veins with a terminal fine and wavy black line. Hind wing from base to subterminal line of the color of fore wing crossed by a short reddish-brown line near base; a short curved line at cell, the postmedial line a continuation of the subterminal line of fore wing; the terminal black line cut by veins. Wings below iridescent, greenish or purplish with the lines reduced to small points.

Expanse: 22 mm.

Habitat: Kartabo, British Guiana.

Type: Cat. No. 34746, U. S. N. M.

LITHOSIINAE.

***Leucotmenis kaietura* sp. nov.**

Female: Palpi black above, orange underneath; head black with a lateral fine orange line; abdomen above rather broadly black with a broad lateral

orange line, underneath dark plumbago slate. Fore wing black; a bluish-white streak in cell and a small white streak, somewhat triangular, post-medially. Hind wing with yellow hairs on inner margin, and a small hyaline spot beyond cell, cut by two veins; cilia on both wings dark bluish-gray. Fore wing below with the white streak in cell broader and more distinct.

Expanse: 25 mm.

Habitat: Kaietur, British Guiana.

Type: Cat. No. 34747, U. S. N. M.

***Prepiella deicoluria* sp. nov.**

Female: Head white; thorax roseate gray; the metathorax with a curved white line; abdomen above pale vinaceous pink with traces of fine dark segmental lines. Fore wing: basal third pallid purple drab outwardly edged by a lunular black line with projecting lines based and a black point at base of costa; medial space bittersweet pink; subterminal space pinkish-white limited by an irregular double black line connected by transverse black lines; termen narrowly pink with white cilia. Hind wing white with some pale pinkish suffusions and a few black spots at apex; fore wing below broadly black on basal third of costa; a medial curved pink space, the subterminal curved space black without the irregular lines of the upper side. Hind wing below pinkish-white with a black spot at apex.

Expanse: 21 mm.

Habitat: Kartabo, British Guiana.

Type: Cat. No. 34748, U. S. N. M.

HEPIALIDAE.

***Phassus guianensis* sp. nov.**

Male: Antennae fuscous. Head, collar and patagia vinaceous rufous, the thorax only visible as a black point. Abdomen dorsally etruscan red with narrow darker segmental lines, underneath paler with broader segmental lines. Fore wing with pale purplish-vinaceous stripes on a light cinnamon drab background; costa narrowly fuscous; a pale triangular patch below base of costa limited by a fine, dark inbent line to inner margin; a pale medial space, its base on costa crossed by three wavy, fine reddish lines; the medial dark space to inner margin crossed by black and pinkish lines, the dark veins partly pinkish; the postmedial dark space narrow on costa, cut by white veins, expanding toward inner margin. The black and white line edging the triangular pale space continued to inner margin with some black spots anteriorly, the posterior half with a black and pink line; the apical pale space with subterminal double pale and darker lunules, toward inner margin with irregular pinkish and black lines; termen with short, irregular, spots and lines; cilia dark brown. Hind wing light russet vinaceous, paler on termen. Fore wing below dark at base becoming pinkish-gray on terminal half with a faint medial line and a wavy postmedial line. Hind wing below slightly paler than on upper surface.

Expanse: 55 mm.

Habitat: Kartabo, British Guiana.

Type: Cat. No. 34749, U. S. N. M.

8.

A Papillary Cystic Disease Affecting the Barbels of *Ameiurus nebulosus* (Le Sueur), Caused by the Myxosporidian *Henneguya ameiurensis* sp. nov.

R. F. NIGRELLI & G. M. SMITH

New York Aquarium; Yale Medical School and New York Aquarium

(Plates I-VIII; Text-figure 1).

INTRODUCTION.

Many of the myxosporidians are histozoic parasites of fishes and cause only slight host tissue responses. Occasionally, lesions are produced that eventually develop into large tumor masses (see Nigrelli & Smith, 1938). The tissue response in such cases manifests itself by the proliferation of fibroblastic material which forms a supportive frame-work for the developing spore masses. The end result in such growths, however, is the degeneration of muscle, bone and other tissues in the path of the growing fibroblasts and spores. It is interesting to note that in many of these myxosporidian infections the inflammatory reaction is invariably mild and only when a secondary bacterial or fungal infection sets in does it become severe, the latter occurring perhaps at the time the tumors rupture to release the mature spores.

As a general rule, histozoic myxosporidians are definitely localized by circumscribing connective tissue. Their effects on host tissues are usually limited to these circumscribed areas and only in certain instances do they cause pathological changes to adjacent tissues and other organs. The present contribution deals with an instance where not only a local phenomenon occurs, but also immediate neighboring tissue responses develop. In the disease to be described here, the myxosporidian infection is localized in the connective tissue layer of the skin of the barbels of the common bullhead. Although the parasites are encapsulated by host tissue and although they elicit degenerative changes within these enclosed areas, nevertheless they also induce pathological changes adjacent to the encapsulated collections of organisms, such as hyperplasia of the overlying epithelium. The details of these two sets of changes will be described below.

The parasites causing this papillary cystic disease belong to the genus *Henneguya* Thélohan. Surprising as it may seem, it is the first myxosporidian species to be described from the common bullhead, *Ameiurus nebulosus* (Le Sueur). This parasite, however, differs sufficiently from other species of *Henneguya* to be considered new and for which the name *Henneguya ameiurensis* is proposed.

MATERIAL AND METHODS.

The infected catfish was taken from a lake in New Hampshire during the summer of 1938. The disease was found in a single fish and attempts to

obtain more material were without success, although a great many fish were examined for this purpose.

The fish was an adult, measuring $7\frac{1}{2}$ inches in total length. As seen in the accompanying drawing (Fig. 1) and photograph (Fig. 2), the disease affected the barbels, especially the two dorsal ones, and the barbel at the angle of the mouth on the right side of the body. Externally there were no other manifestations of the disease and the fish appeared normal in all other respects.

The bases of the affected barbels were completely surrounded by tumor masses (Figs. 1, 2). On closer inspection these masses had a very distinct, irregular papillary appearance. The parts of the barbels distal to the lesions, however, were normal in appearance.

The material was fixed in 10% formalin and numerous blocks were prepared for histological studies. They were sectioned at 5-10 microns and stained with hematoxylin-eosin, Giemsa's, Mallory's and Masson's.

DESCRIPTION OF *Henneguya ameiurensis* SP. NOV.

Vegetative Stages: The cysts containing the masses of organisms were found in the dermal connective tissue of the barbels (Figs. 3, 4, 5). The cysts varied considerably as to shape and in size. In certain cross sections of the barbels as many as fifteen cysts were found, of which a few were spherical but the majority of which were oval or irregular in shape. They measured from .190 x .342 to .760 x 1.22 mm. In practically all instances, the cysts were matured, containing for the most part fully developed spores. However, pansporoblasts were present at the periphery of the cysts, but in the majority of the cases they were fairly well advanced in their development. In younger cysts all stages of sporogenesis were recognized (Figs. 6, 7). The pansporoblasts are disporous, although monosporous forms were evident. *Henneguya ameiurensis* is polysporous.

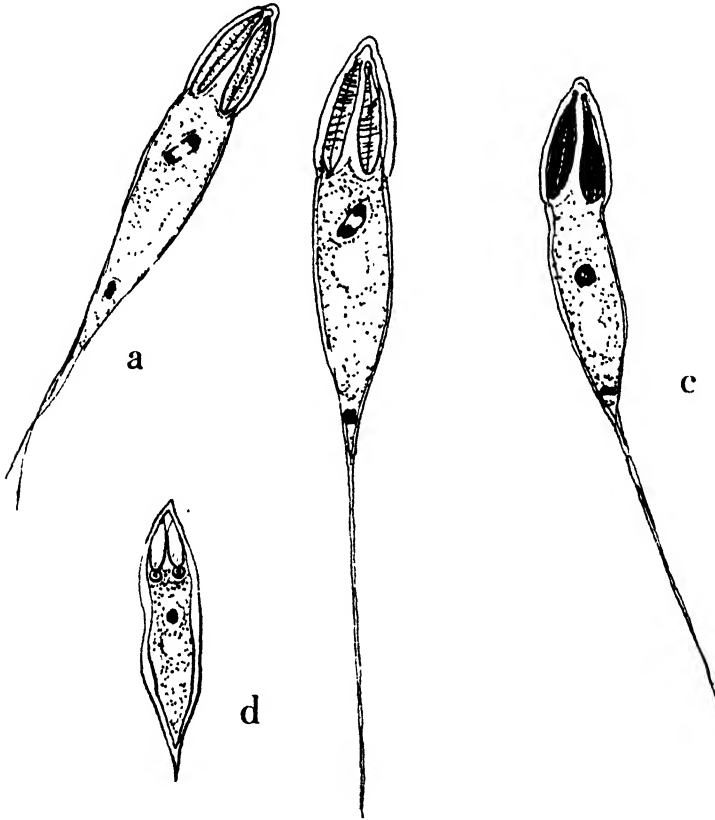
The young sporonts are spindle-shaped organisms. Polar capsule nuclei are present and the sporoplasm contains but a single nucleus (Text-fig. 1, d). As the sporont becomes mature, the definite capsules are completely developed and the shell with the posterior process begins to elongate (Figs. 6, 7). The two nuclei found in the adult spore appear to be the result of a subsequent division, for many spores were found with dividing nuclei in the telophase stage (Text-fig. 1, a, b). According to Kudo (1926), the sporont of many Myxosporidia contains six nuclei, two of which form the capsule, two for the shell and two remain as the nuclei of the sporoplasm.

It is interesting to report here that many uninucleate, irregular shaped organisms were encountered within the cysts, scattered among the matured spores. These have been interpreted by us as newly released sporoplasms which will perhaps migrate from the cysts into adjacent tissues and set up new foci of infections. Such possible migrations might also explain certain connective and epithelial reactions encountered in these preparations.

Spores: The spores are more or less lanceolate in shape, being approximately six times as long as they are broad (Text-fig. 1; Figs. 8, 9, 10, 11). The mature forms average about 23.3 microns in length, 4.1 microns in width, 3.0 microns in thickness. The posterior process varies considerably in length and thickness. The more elongated the process, the thinner it is. However, the length measurements for this process vary from 15-41.5 microns. The process is an extension of the shell material and therefore composed of two halves. Occasionally they may be separated along the posterior tip, giving it a bifurcated appearance (Text-fig. 1a).

The sporoplasm is granular and in the majority of forms binucleated. Uninucleate stages were rare in our material. A small iodophilous vacuole was occasionally found anterior to the nuclei but most always it was found

posterior to them. At the posterior end of the sporoplasm, at about the point where the posterior process begins, one or two deeply staining basophilic granules are always present, (Text-fig. 1; Fig. 11). The nature of these granules is unknown, although they have been seen and described by other investigators (e. g., Gurley, 1888).



Text-fig. 1.

Henneguya ameiurensis sp. nov. from the barbels of the common bullhead, *Ameiurus nebulosus*. **a**, **b**, **c**, mature spores. Note dividing nuclei in **a** and **b**. **c**, uninucleate spore. **d**, young spore with uninucleate sporoplasm and two polar capsule nuclei. $\times 1500$.

Although the general shape of the shell is lanceolate, there is a characteristic indentation at the level of the posterior end of the polar capsules (Text-fig. 1; Fig. 10). The sutural ridge is faintly evident. The polar capsules measure on the average about 5.4 microns in length and 1.6 microns in width at their greatest diameter. They do not, however, fill the entire anterior end of the shell. The anterior end of the shell tapers slightly at the tip, giving it a blunt conical appearance.

The staining reactions of the spores to the various techniques used may be mentioned here. With Masson's stain the shell, capsules and vacuole are colored a very dark green; polar filaments and sporoplasm take on a red color; while the nuclei are stained a deeper red. With Mallory's stain the shell and capsules are colored yellowish; sporoplasm is orange; nuclei and posterior sporoplasmic granules take on a light blue color. With Giemsa's

stain the polar filaments take on a deep blue-green color; shell and extension are a lighter blue-green color; sporoplasm and vacuole take on a pinkish color.

In several of the cysts, spores with three and four polar filaments and nuclei were encountered. Similar spore abnormalities were described by Schäferna & Jirovec (1931) for *Henneguya acerinae*.

Comparisons: *Henneguya ameiurensis* appears to be closely related to *H. gurleyi* Kudo (1910 (= *Myxobolus* cf. *linearis* Gurley, 1894), a species found in lesions at the base of the spines of the second dorsal fin of *Ameiurus melas*. However, *H. ameiurensis* differs from *H. gurleyi* in the shape of the shell and in size measurements, two important diagnostic characters. *Ameiurus nebulosus*, the common bullhead, insofar as is known to the authors, is a new host species for which a myxosporidian infection has been reported.

DESCRIPTION OF THE MYXOSPORIDIAN LESION IN *Ameiurus nebulosus*.

The cross section of the barbel, including the tumor, reveals the fact that the tumor mass arises from the skin at the base of the barbel (Figs. 3, 4). Part of the tumor is composed of numerous cystic cavities separated by connective tissue septa (Fig. 5). These cavities contain the organisms referred to above. Each cyst is surrounded by a dense fibrous capsule varying in thickness from 6 to 16 microns. The septum separating two adjacent cysts is formed also from fibrous tissue varying somewhat in density. This enclosing fibrous tissue is composed of fusiform connective tissue cells, in places hyalin, with here and there a few scattered lymphocytes. The inner lining of the cysts is formed of very flattened fibroblastic cells. In contact with the inner lining may be found globular or slightly flattened masses which are the developing schizonts of *Henneguya ameiurensis* (Figs. 5, 6, 7). The remainder of each cavity is loosely packed with large numbers of young and matured spores.

It is obvious that the cysts occupy the region directly below the epithelium; that is, they lie in the corium or just below this layer.

All of the cysts seem to contain varying amounts of a stringy mucoid substance in which may be found embedded small numbers of spores. Other cysts contain, beside the mucoid material, lymphocytes, some fibroblasts and occasional melanophores (Fig. 12). The presence of these cellular elements invading the cavity may indicate an early healing response. Later stages of repair were not encountered in our material. It would be interesting to know the final fate of the cysts and their contents, for it might shed light on the subsequent stages of the developmental cycle of these organisms. Our recent studies on lymphocystic disease in its later stages has indicated the probable fate of these large hypertrophied cells characteristic of the disease by a rupture of the hypertrophied lymphocystis cell, permitting the escape of their contents into the surrounding water (Nigrelli & Smith, 1939). Here, again, the same outcome may be effected, particularly as we find in greatly distended cysts occasional areas of thin overlying epithelium.

As stated earlier in this paper, the finding of released sporoplasms may indicate that reinfection of adjacent tissues occurs when these organisms migrate from the cysts, without actual rupture of the cyst wall.

As a rule, however, the epithelium is considerably thickened over the infected area, giving the lesion a papillary or warty appearance. The epithelium is composed of many layers and contains mucus cells and giant dermal gland cells, the latter referred to in German literature as "Kolben Zellen" (Figs. 13, 14). Reed (1924) has called these last-named giant cells dermal gland cells and according to him they arise from elements which he termed "clavate" cells. Dermal gland cells are demonstrated very clearly in our material, as can be seen in Fig. 15. They are often binucleate and stain

a faint pink or yellow color with eosin and Masson's respectively. Their nuclei are intensely basophilic. Such cells seem to be plentiful in the normal skin of the catfish barbel. In the infected barbel, however, they appear to be increased in numbers, just as are the mucus and squamous cells of the overlying skin. Their exact function is not known.

The sensory end organs are retained in the hyperplastic skin overlying the tumors without evidence of degeneration. They probably are not increased in numbers (Fig. 16).

Melanophores are of very frequent occurrence in the papillary epithelium and in places suggest a definite hyperplasia of this type of cell (Fig. 17).

Histological examination of sections of other organs and tissues of the catfish showed their structure apparently normal in all respects.

DISCUSSION.

Tissue responses to myxosporidian infections have been reported by other investigators (Gurley, 1893; Hahn, 1915, Kudo, 1926, 1929; Bond, 1938; etc.). Kudo (1926, 1929) has noted and described the histo-pathology in lesions due to Myxosporidia, and in 1929 he reported the development of a hyperplastic growth of the epithelium of the gills in channel catfish, *Ictalurus punctatus*, infected with *Henneguya exilis*. In these catfish, the parasites are encysted on the gill lamellae, and the surrounding tissue responded to the infection by an enormous hyperplastic growth of the adjacent epithelium together with a severe inflammatory reaction. In the present case, the inflammatory reaction is a mild one but there is a definite hyperplasia of the epithelium overlying the subcutaneous infected regions, and such specialized cells as melanophores, mucus and dermal gland cells found in the epithelium are involved to a certain extent in this hyperplasia.

SUMMARY.

1. A papillary cystic disease is described affecting the barbels of *Ameiurus nebulosus* (Le Sueur).
2. The parasite producing this disease is a new species of *Henneguya* Thélohan, for which the name *H. ameiurensis* is proposed.
3. The spores are more or less lanceolate in shape, measuring 23.3 x 4.1 x 3.0 microns. The posterior shell extension, characteristic of the genus, varies considerably in length and thickness.
4. The binucleate condition of the mature sporoplasm appears to be the result of division of the nucleus in a slightly earlier stage of the spore.
5. The pansporoblasts are disporous, although monosporous forms do occur. This myxosporidian species is polysporous.
6. *H. ameiurensis* is the first myxosporidian parasite to be described from the common bullhead.
7. The various tissue responses of the host to this form of myxosporidian infection is described.

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EXPLANATION OF THE PLATES.

PLATE I.

- Fig. 1. Drawing of a formalin-fixed specimen of *Ameiurus nebulosus*, showing papillary cystic disease at the bases of the dorsal barbels. Drawing by Clare Smith.
- Fig. 2. Photograph of a front view of the catfish, demonstrating the papillary cysts of the dorsal barbels and the barbel at the angle of the mouth on the right side.
- Fig. 3. Photomicrograph showing distribution, number, size and shape of the myxosporidian cysts in a cross-section of one of the catfish barbels. $\times 50$. H-E.

PLATE II.

- Fig. 4. Papillary cystic tumor caused by *Henneguya ameiurensis* arising from the base of a dorsal barbel. $\times 16$. H-E.
- Fig. 5. Higher magnification of section shown in Fig. 3. The organisms fill the entire cavity of each cyst. Note the vegetative masses at the periphery of the cysts. Note also the intercystic septa. $\times 125$. H-E.

PLATE III.

- Fig. 6. Photomicrograph showing the vegetative masses of *Henneguya ameiurensis* at the periphery of the cyst. Pansporoblasts, sporonts and young spores can be recognized. $\times 350$. H-E.
- Fig. 7. Photomicrograph of a slightly later stage than that shown in Fig. 6. Here sporogenesis is almost completed. $\times 500$ H-E.

PLATE IV.

- Fig. 8. Photomicrograph of young spores. $\times 400$. H-E.
- Fig. 9. Fully developed spores of *Henneguya ameiurensis*. Posterior extensions of the valves not in focus. $\times 1400$. H-E.

PLATE V.

- Fig. 10. Higher magnification of the spores. Note outline of the shell. $\times 1700$. H-E.
- Fig. 11. Mature spores. Spore in upper right-hand corner shows split posterior process and posterior basophilic granule. $\times 1500$. H-E.

PLATE VI.

- Fig. 12. Photomicrograph showing cysts with stringy mucoid material, lymphocytes, fibroblasts and isolated spores. Perhaps an early stage in healing giant dermal gland cells $\times 125$. H-E.
- Fig. 13. Photomicrograph showing the host tissue responses. Note the thickened epithelium, composed of many layers of epithelial cells, mucus cells and giant dermal gland cells. $\times 125$. H-E.

PLATE VII.

- Fig. 14. Higher magnification of the thickened epithelium shown in Fig. 13. $\times 350$.
- Fig. 15. Giant dermal gland cells found in the skin of the barbel of the catfish. A slight hyperplasia is to be noted for these cells in the infected barbel. $\times 400$. H-E.

PLATE VIII.

- Fig. 16. Sensory end-organ in the hyperplastic skin overlying the myxospordian tumors. No degenerative changes are to be noted for these structures. $\times 350$. H-E.
- Fig. 17. Melanophores in the skin of infected portion of the barbels. The frequent occurrences of these cells in the papillary epithelium suggests a definite hyperplasia of this type of cell. $\times 275$. H-E.



FIG 1

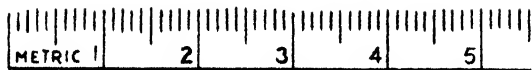


FIG 2



FIG 3

A PAPILLARY CYSTIC DISEASE AFFECTING THE BARBELS OF AMEIURUS NEBULOSUS (LE SUEUR) CAUSED BY THE MYXOSPORIDIAN HENNELCUIA AMEIURENSIS
SP. NOV



FIG 4

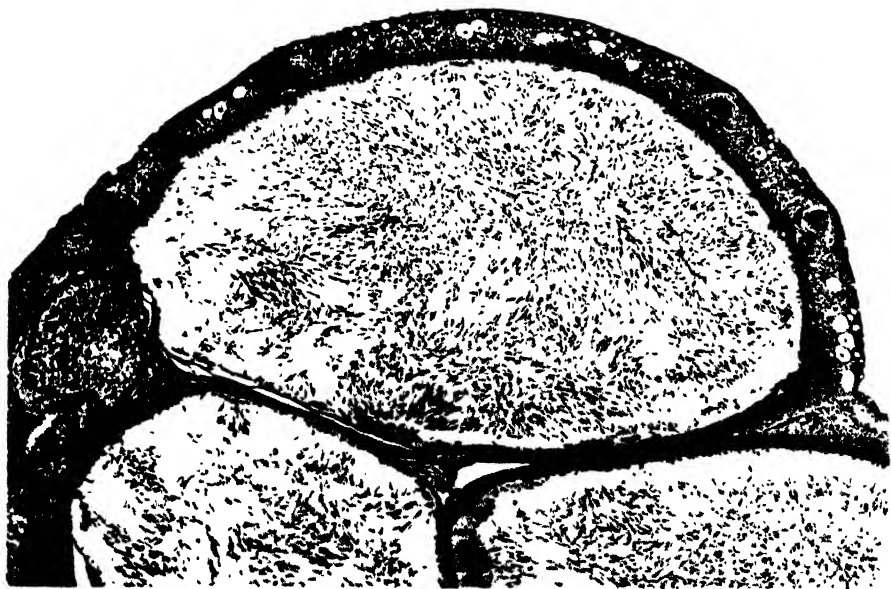


FIG 5

A PAPILLARY CYSTIC DISEASE AFFECTING THE BARBELS OF AMEIURUS NEBULOSUS (LE SUEUR), CAUSED BY THE MYXOSPORIDIAN HENNEGUYA AMEIURENSIS SP. NOV.



FIG 6



FIG 7

A PAPILLARY CYSTIC DISEASE AFFECTING THE BARBELS OF AMEIURUS NERI
LOSUS LI SUEUR CAUSED BY THE MYXOSPORIDIAN HENNEGUYA AMEIURENSIS
SF NOV



FIG. 8



FIG. 9

A PAPILLARY CYSTIC DISEASE AFFECTING THE BARRELS OF AMELRIS NEBULOSUS (L. SUEUR) CAUSED BY THE MYXOSPORIDIAN HENNELLYA AMELRENTI

SP. NOV.



FIG 10



FIG 11

A PAPILLARY CYSTIC DISEASE AFFECTING THE BARBELS OF *AMEIURUS NEBULOSUS* (LE SUEUR), CAUSED BY THE MYXOSPORIDIAN *HENNEGUYA AMEURENSIS* SP. NOV.

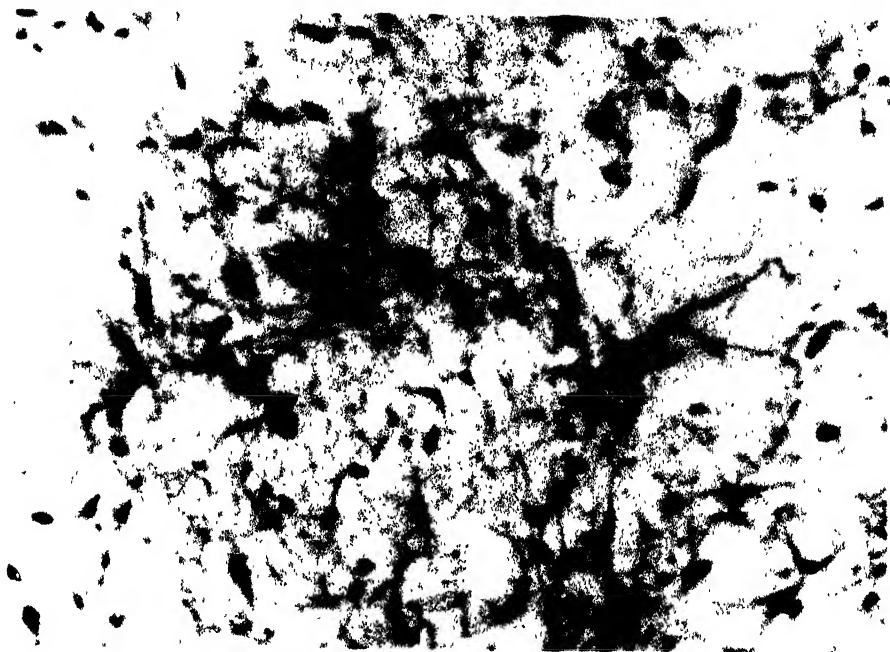


FIG. 12.

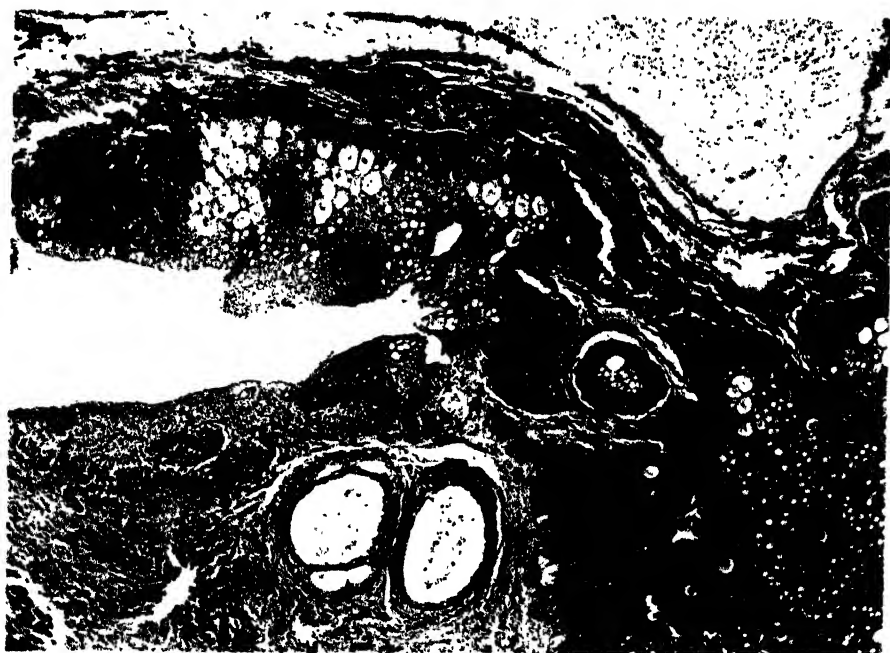


FIG. 13.

A PAPILLARY CYSTIC DISEASE AFFECTING THE BARBELS OF AMEIURUS NEBULOSUS (LE SUEUR), CAUSED BY THE MYXOSPORIDIAN HENNEGUYA AMEIURENSIS
SP. NOV



FIG. 14

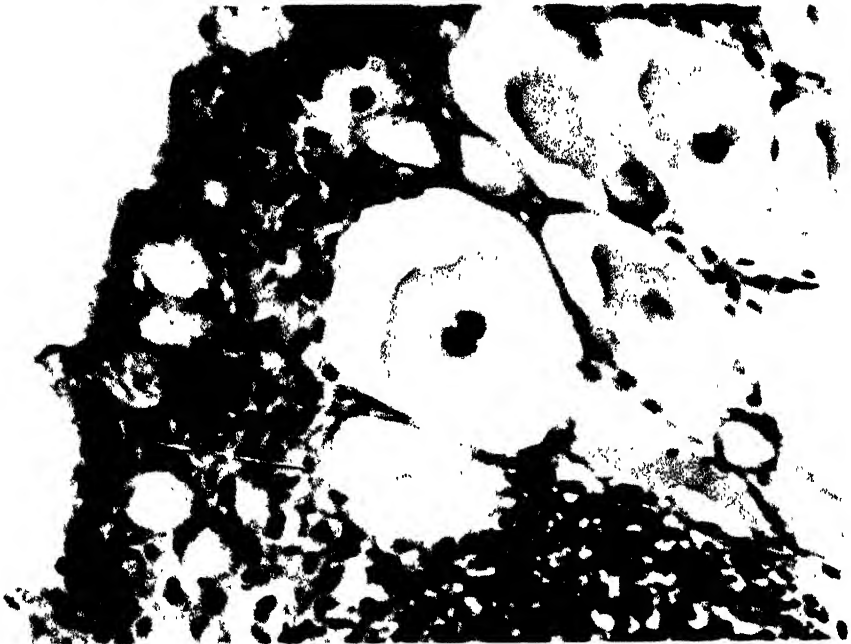


FIG. 15.

A PAPILLARY CYSTIC DISEASE AFFECTING THE BARBELS OF *AMEIURUS NEBULOSUS* (LE SUEUR), CAUSED BY THE MYXOSPORIDIAN *HENNEGUYA AMEIURENSIS* SP. NOV

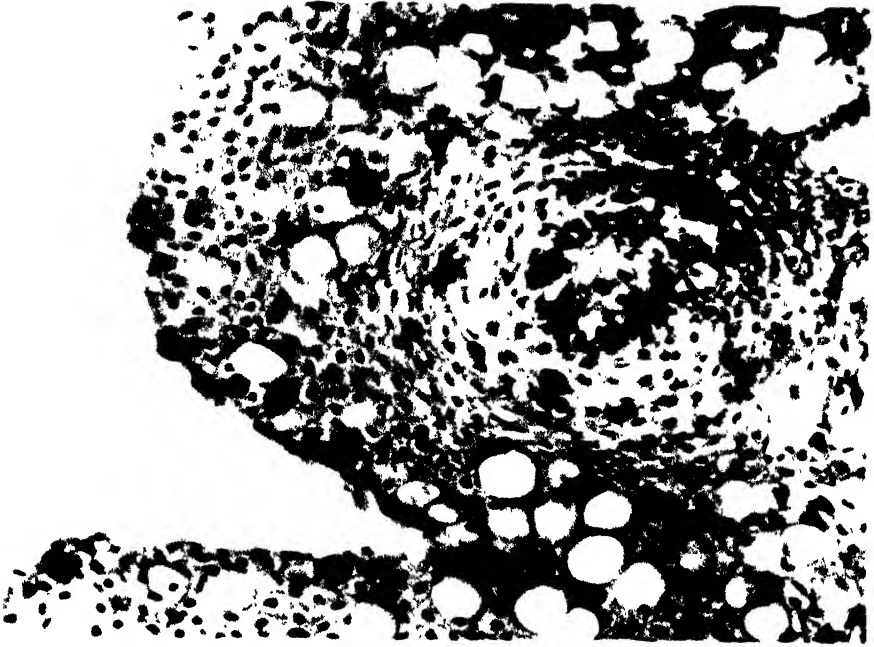


FIG. 16.



FIG. 17.

A PAPILLARY CYSTIC DISEASE AFFECTING THE BARBELS OF AMEIURUS NEBULOSUS (LE SUEUR), CAUSED BY THE MYXOSPORIDIAN HENNEGUYA AMEIURENSIS SP. NOV

9.

Caudal Skeleton of Bermuda Shallow Water Fishes. IV.
Order Cyprinodontes: Cyprinodontidae, Poeciliidae.¹

GLORIA HOLLISTER

Department of Tropical Research.

(Text-figures 1-17).

OUTLINE.

	Page
Introduction	97
Bermuda Cyprinodontes:	
Cyprinodontidae: <i>Fundulus bermudae</i>	98
Key	99
Poeciliidae	
<i>Mollienesia sphenops</i>	101
<i>Gambusia holbrooki</i>	106
<i>Lebistes reticulatus</i>	109
Summary	112

INTRODUCTION.

This is the fourth of a series of papers dealing with the caudal skeleton of Bermuda fishes.² The shallow-water Iniomi of Bermuda is represented by two families, four genera and four species. Of these, *Fundulus bermudae*, a Cyprinodontidae, is a native, whereas all the Poeciliidae have been introduced. *Gambusia holbrooki*, a common species of the Eastern States from Delaware to Florida and now thriving in Bermuda marshes, was brought from fresh-water ponds near Washington, D. C., and planted in Pembroke Marsh and others in May, 1928. *Gambusia* thrive in our Bermuda fresh-water pools at Nonsuch as well as in the brackish marshes where they serve to control the breeding of mosquito larvae. Dr. Henry Wilkinson of the Medical and Health Department of Bermuda reports that, "for the most part they have done extremely well in brackish marshes. In some places, however, as Shelly Bay, they do not always last, but I think birds are the difficulty there and not salinity or other chemical substances. This fish is most adaptable. They stay near the surface, use their upturned mouth for mosquito larvae and give birth to a multitude of live fish. About half the *Gambusia* died coming here from Washington. The survivors were put directly into the various marshes and did well everywhere except in the marsh at Baileys Bay (which has since been filled). For this marsh a few of them had to be adapted by gradually stepping up the salinity in a bowl."

¹ Contribution No. 593, Department of Tropical Research, New York Zoological Society.

Contribution from the Bermuda Biological Station for Research, Inc.

² Caudal Skeleton of Bermuda Shallow Water Fishes. I. Order Isospondyli: Elopidae, Megalopidae, Albulidae, Clupeidae, Dussumieriidae, Engraulidae. *Zoologica*, New York Zoological Society, Vol. XXI, Dec. 31, 1936.

Caudal Skeleton of Bermuda Shallow Water Fishes. II. Order Percomorphi, Suborder Percosoces: Atherinidae, Mugilidae, Sphyraenidae. *Zoologica*, New York Zoological Society, Vol. XXII, Oct. 7, 1937.

Caudal Skeleton of Bermuda Shallow Water Fishes. III. Order Iniomi: Synodontidae. *Zoologica*, New York Zoological Society, Vol. XXII, Dec. 31, 1937.

During a series of experiments to determine "Salt and Fresh-water Viability of Fish"⁸ I found that *Gambusia* need a few days (one day was successful in several cases) in a 50-50% solution, before thriving in pure sea-water. Placed directly in sea-water they survive about three hours. Later it was found that of the minnows the guppy is the least adaptable to salt-water, needing gradual changes over a period of about a week. *Fundulus* adapts itself more readily than the others to either fresh or salt water, without any intermediate steps in half-and-half solutions. Recently *Lebistes* and *Mollienisia* have been taken to Bermuda and placed in garden lily pools, where they thrive all the year around.

For Caudal Fin Terminology, Caudal Bibliography, and method of preparing specimens for this study refer to Caudal I. The length of specimens in this paper is standard length unless otherwise stated.

The symbols used in the figures are 1C, 1st caudal vertebra; 2C, 2nd caudal vertebra; 3C, 3rd caudal vertebra; EP, epural; 1, 2, 3, hypurals; T, last trunk vertebra.

I am indebted to Dr. and Mrs. Carl Hubbs for a complete series of *Mollienisia sphenops* which range in age from less than 24 hours to 9 weeks, as well as adults with an exact record of their ages when they were placed in spirits; to Curator Lee S. Crandall, Keeper Scott and Head Gardener George Skene for adult and young *Lebistes*; to Dr. Henry Wilkinson for information concerning the introduction of *Gambusia* to Bermuda; to Thatcher Adams for collecting *Gambusia* from the Bermuda marshes; to Dr. William Beebe, Director of this Department, and Mr. John Tee-Van, General Associate, for their cooperation.

The drawings are by Miss Harriet Bennett and Miss Janet Wilson.

1. *Fundulus bermudae* Günther.

(Text-fig. 5).

Diagnostic Characters:

Caudal fin count not less than 20, usually $8 + \frac{12}{19} + 12$.

Caudal raylets extend anteriorly to approximately the fifth posterior neural and haemal spines.

No modification of ventral structure of anterior caudal vertebrae adjacent to the anal fin in male. Anal fin in male and female similar in this oviparous fish.

5 posterior neurals and haemals elongated into the caudal contour.

Vertebral count: 12 to 14 trunk, plus 19 to 21 caudal. Total 31, 33, 35.

1 epural.

1 large fan-shaped hypural and 1 slender ventral hypural.

Material Studied.

Length.	KOH Cat. No.	Cat. No.	Text-fig. No.
81 mm.	1105	25,113	5
76 mm.	1106	25,113	
72 mm.	2226	25,112	
(4) 66-61 mm.	1109	25,113	
59-56 mm.	2226	25,112	
(4) 54-46 mm.	1108	25,113	
44 mm.	2226	25,112	
(8) 42-26 mm.	1107	25,113	

⁸Hollister, 1934. Salt and Fresh Water Viability of Fish. New York Zoological Society Bulletin, Vol. XXXVII, No. 6, Nov.-Dec., 1934.

Breder, 1934. Ecology of an Oceanic Fresh-water Lake. Zoologica, New York Zoological Society, Vol. XVIII, No. 3, August, 1934. See Bibliography.

KEY TO CAUDAL FIN OF BERMUDA SHALLOW WATER CYPRINODONTID FISHES.
(Text-figs. 1-4).

Group I CYPRINODONTIDAE

Fundulus bermudae

Caudal fin count not less than 20, usually $8 + 12$.
 $\frac{19}{7 + 12}$

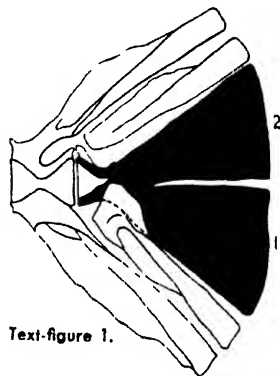
Caudal raylets extend anteriorly to approximately the fifth posterior neural and haemal spines.

No modification of ventral structure of anterior caudal vertebrae adjacent to anal fin in male.

Sub-Group A *Mollienisia sphenops*

Caudal fin count usually $15-16$ or 16 .
 $\frac{16}{15}$

Median hypurals completely divided in mid-line forming a dorsal and ventral half



Text-figure 1.

Group II POECILIDAE

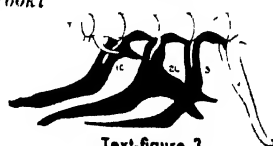
Caudal fin count less than 20.
 $\frac{19}{19}$

Caudal raylets extend anteriorly to approximately the third posterior neural and haemal spines.

Modification of ventral structure of anterior caudal vertebrae adjacent to anal fin in male.

Division I *Gambusia holbrooki*

Modification of anterior three caudal vertebrae in male.
Caudal vertebrae 18 to 20.
Total vertebrae 31 to 33;
 $13 + 18$ to 20.

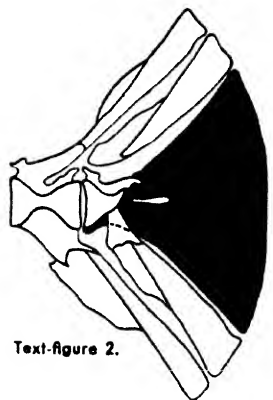


Text-figure 3.

Sub-Group B

Caudal fin count less than A, usually $\frac{12}{13}$ or $\frac{13}{13}$

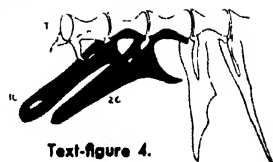
Median hypural not completely divided in mid-line.



Text-figure 2.

Division II *Lebistes reticulatus*

Modification of anterior two caudal vertebrae in male.
Caudal vertebrae 14 to 17.
Total vertebrae 26 to 29;
 $12 + 14$ to 17.

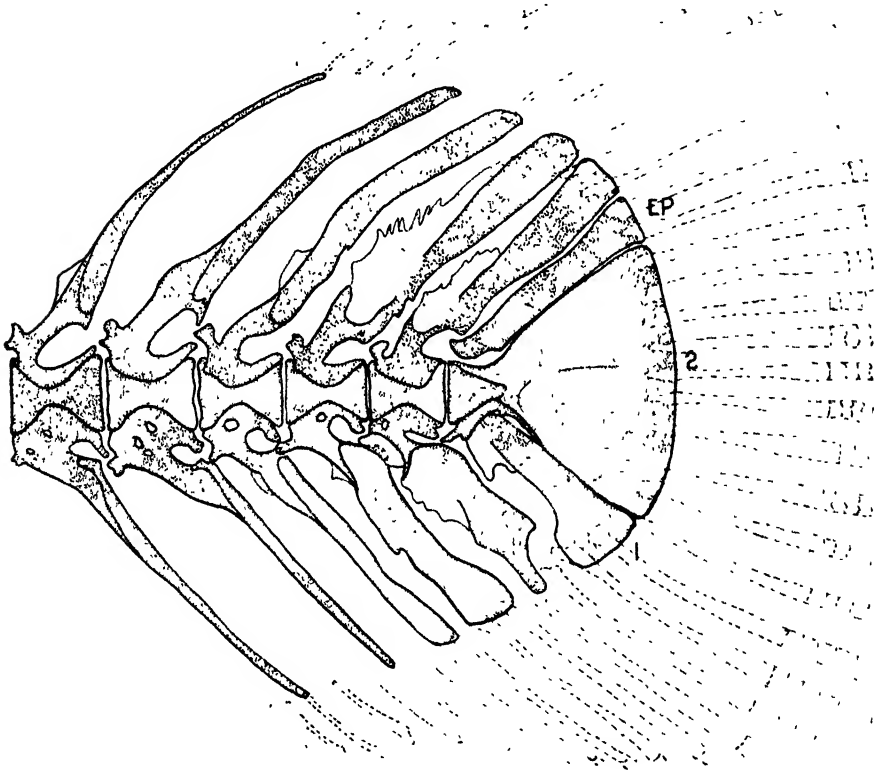


Text-figure 4.

Caudal Osteology.

Urostyle: Separate segments of the urostyle cannot be found in any specimens examined which range in size from 26 mm. to 81 mm. The urostyle is conical in shape and the blunt posterior end can be seen in some specimens at the base of the fan-shaped hypural. The urostyle appears completely consolidated with the median hypural.

Uroneurals: In several of the smaller specimens a slender paired bone extends along the dorsal surface of the fan-shaped hypural. This may be a uroneural. In larger specimens this cannot be seen but in all there is a marked irregularity in the shape and size of the reduced neural on the anterior part of the urostyle.



Text-figure 5.

Fundulus bermudae. Length 81 mm. and largest in collection. Shows solid dorsal hypural, raylets reaching as far forward as fifth from last neural and haemal, and wing growths on the posterior neurals and haemals which are irregular in the different specimens. $\times 15.4$.

Hypurals: There are two hypurals in all specimens studied. The dorsal fan-shaped hypural is three and a half times wider on the distal margin than the second hypural. The larger bone is median and terminal in position and supports about ten caudal rays. There are no lines to indicate that this large hypural is a fusion of several bones, but very young specimens are not available. The smaller hypural is entirely ventral in position with its base abutting the ventral surface of the cone-shaped urostyle. In all specimens the size and shape of the smaller hypural is irregular. In larger fish there is a thin wing on the anterior surface. There is also marked variation

in position of the base of the hypural. In some specimens this is close to the urostyle but in others there is considerable space between. In one large specimen the distal half of the smaller hypural is fused with the adjacent and ventral side of the larger hypural.

Epural: There is one epural in all of our specimens. This bone is similar in shape and position to the ventral hypural and the two flank respectively, the anterior ventral and the anterior dorsal surfaces of the median fan-shaped hypural. The basal end of the epural varies in exact position in the different specimens, which is also seen in the base of the hypural which is opposite.

Caudal Fin Ray Count:

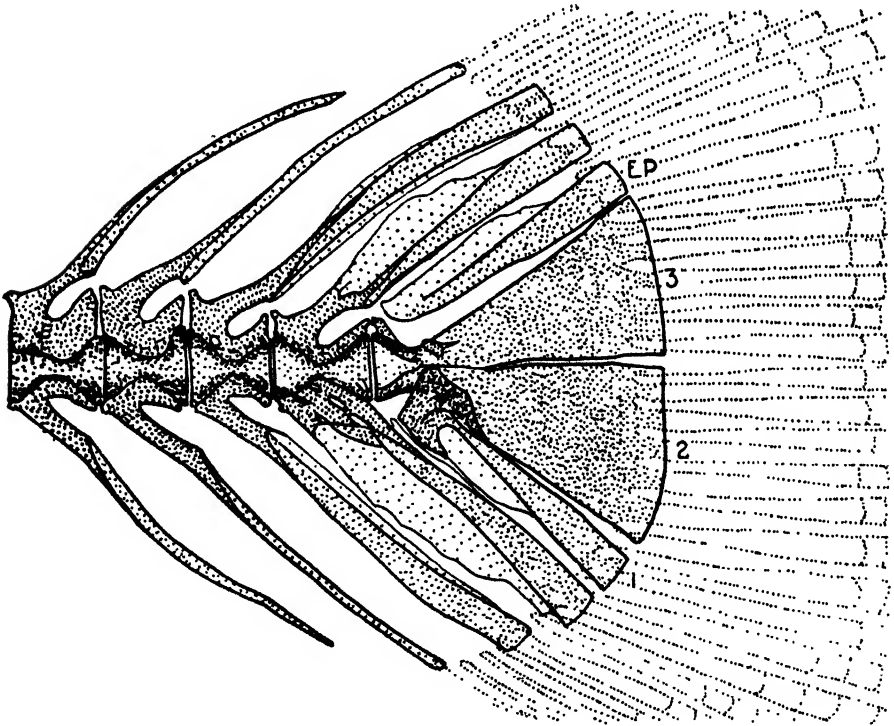
$$\frac{7 \text{ or } 8 + 12}{7 \text{ or } 8 + 12} = \frac{19 \text{ or } 20}{19 \text{ or } 20}$$

2. *Mollienisia sphenops* (Cuvier & Valenciennes).

(Text-figs. 6-11).

Diagnostic Characters:

Caudal fin count usually $\frac{16}{16}$ or 1 more or less.



Text-figure 6.

Mollienisia sphenops. Adult female, length 38 mm. This is typical of the adult male and female and shows the two large median hypurals characteristic of this species. $\times 27.5$.

Diagnostic Characters (continued):

Caudal raylets extend anteriorly to approximately the third posterior neural and haemal spines.

Modification of two anterior caudal vertebrae in male. Anal fin in male specialized in this viviparous species.

3 posterior neurals and haemals elongated into the caudal contour.

Vertebral count: 12 trunk, plus 16 to 18 caudal. Total 28 to 30.

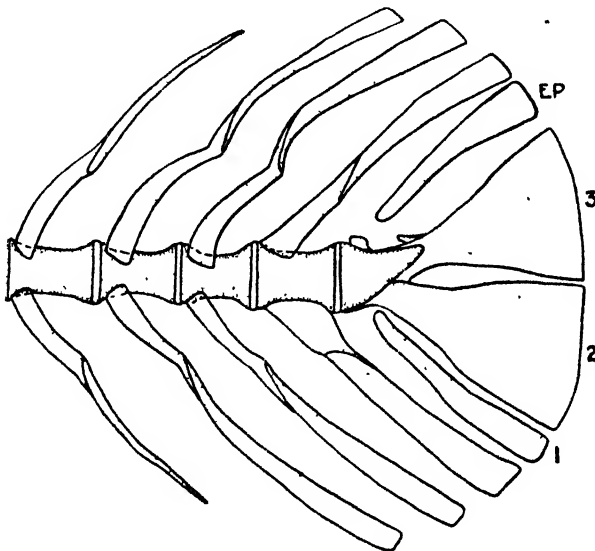
1 epural.

2 large hypurals and 1 slender hypural.

Material Studied.

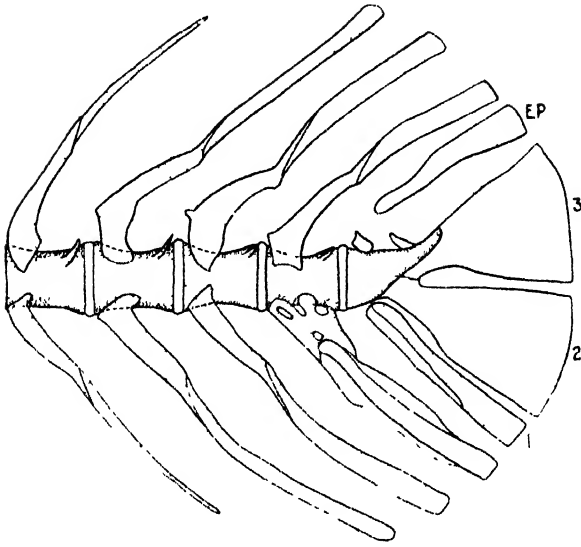
Drawings and descriptions are made from *Mollienisia sphenops* from Acapulco, Mexico. The key is based on this material also.

	Length.	KOH Cat. No.	Text-fig. No.
(2) 1 day or less old	7 mm.	2211	7
(2) 1 week old	8 & 9 mm.	2212	8
(2) 2 weeks old	10 mm.	2213	9
(1) 3 weeks old	12 mm.	2214	10
(2) About 3 weeks old	12 mm.	2215	
(2) About 4 weeks old	14 mm.	2216	
(2) About 5 weeks old	15 mm.	2217	
(2) About 6 weeks old	16 mm.	2218	
(2) 7 weeks old	17 mm.	2219	
(2) 9 weeks old	18 mm.	2220	
(2) About 9 weeks old	18 mm.	2221	
(5) Adults (S AC stock), 3 females	31 mm. & (2) 38 mm.	2248	6
2 males	26 mm. & 29 mm.	2248	11



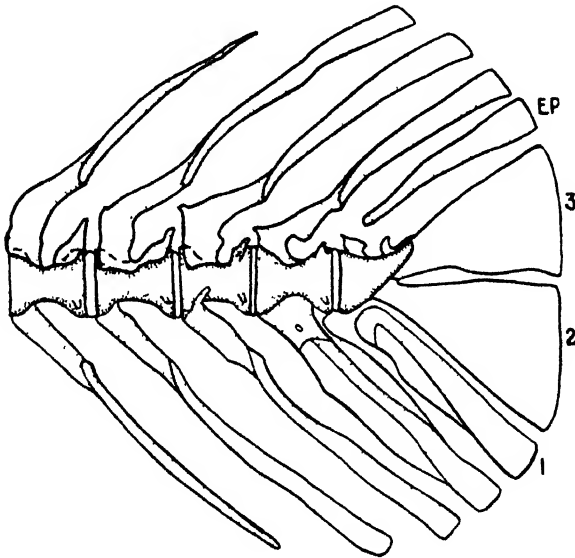
Text-figure 7.

Mollienisia sphenops. 1 day old, length 7 mm. Shows delicate ossification of the caudal area which diminishes gradually toward the distal ends of the neurals, haemals and hypurals. The urostyle is upturned and longer than the older specimens. The column is unsegmented. Wing growths have not developed on the posterior neurals and haemals. As in the adults, the two large hypurals are differentiated. $\times 73.5$.



Text-figure 8.

Mollienisia sphenops. 1 week old, length 9 mm. Shows general increase of ossification and the urostyle elongated and upturned and the column still unsegmented. Appearance of dorsal posterior zygapophyses and wing growths on the last ventral haemal spine and the first hypural. $\times 57.2$.



Text-figure 9.

Mollienisia sphenops. 2 weeks old, length 10 mm. The centra show the spool-shape of the adult. The column is unsegmented and there is a continued increase in ossification. $\times 50$.

***Mollienisia sphenops* ssp.**

From Lake Petén, Guatemala.

(2) Less than 24 hours old	2232
(2) 1 week old	2233
(2) 2 weeks old	2234
(2) 3 weeks old	2235
(1) 4 weeks old	2236
(2) About 4½ weeks old	2237
(1) 4 weeks old	2238
(2) 5 weeks old	2239
(2) 6 weeks old	2240
(2) 7 weeks old	2241
(1) About 7 weeks old	2242
(2) About 8 weeks old	2243
(2) 9 weeks old	2244
(6) Adults	2249

From Subine River, Guatemala.

(2) Less than 24 hours old	2228
(2) 1 week old	2229
(2) 2 weeks old	2230
(2) 3 weeks old	2231

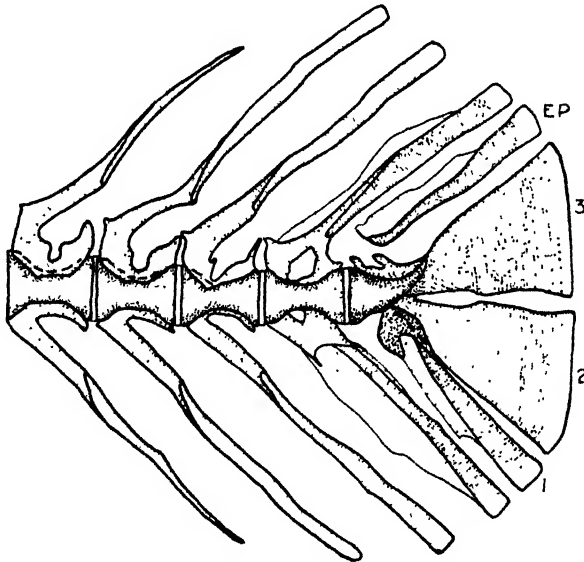
‘ “Sail-fin” variety.

From New York City—Tank-bred.

(2) Adults	2227
(1) Adult male	2206

Caudal Osteology.

Urostyle: In adult specimens the terminal tip of the urostyle is very much reduced and in some hidden by the basal structure of the hypurals.



Text-figure 10.

Mollienisia sphenops. 3 weeks, length 12 mm. Degree of ossification and general shape of bones the same as stages between this age and the adult. Column still unsegmented but in a specimen slightly older the centra are separate. $\times 39.8$.

No separate segments can be found in any growth stages. In the young fish from one day to nine weeks of age the terminal end of the urostyle is up-turned and prolonged. Reduced paired neurals are present in all stages and there is variation in size and shape.

Uroneurals: There is no evidence of uroneurals.

Hypurals: There are three hypurals in young and adult specimens of all stages—two large median bones and one slender ventral hypural. The two large bones are approximately the same size and together form the posterior caudal contour and support approximately twelve rays. With high magnification a line can be found continuing anteriorly from the open median slit in all specimens. In one small specimen there is space between the two bases but in others the bases appear as one. There is considerable ossification in the caudal region of the young of this viviparous species. The third hypural is ventral in position and the basal part of the two lateral sides of the arch overlap the base of the adjacent hypural. The thin wing of bone on the anterior side varies in length and shape in the adult and is not present in the very young specimens.

Epural: There is a single epural in all specimens, which resembles the small hypural without the arch. In young specimens there is no wing-growth present.

Caudal Fin Ray Count:

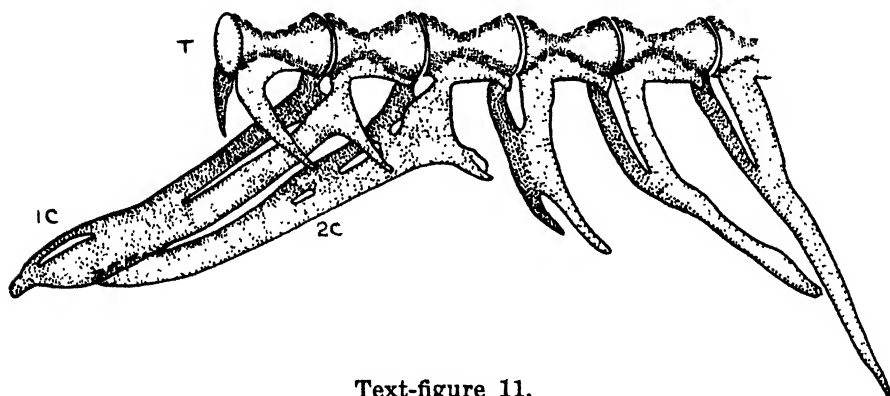
$$\frac{3 + 12}{3 + 13} \quad \frac{3 + 13}{3 + 13} \quad \frac{3 + 12}{2 + 13} = \frac{15}{16} \quad \frac{16}{16} \quad \frac{16}{15}$$

In the subspecies from Lake Petén, Guatemala, the count is;

$$\frac{4 + 12}{5 + 12} \quad \frac{5 + 12}{5 + 12} = \frac{16}{17} \quad \frac{17}{17}$$

In addition to the increase in the anterior raylets, in most specimens the fourth posterior neurals and haemals are prolonged into the caudal contour. In none of the *sphenops* is this found.

Additional Characters Worthy of Note: A paper on the caudal skeleton of cyprinodonts would hardly be complete without mention of the specialized caudal haemals found in the male poeciliids. As in *Gambusia* and *Lebistes*,



Text-figure 11.

Mollienisia sphenops. Anterior caudal haemals of adult male, length 29 mm. The last trunk, or abdominal process, is followed by the first and second caudal which are specialized in the male. The first caudal has an opening in the tip for the insertion of the dorsal ends of the posterior interhaemals. The two openings in the second caudal are not constant in all of the specimens. The ribs and neurals have been omitted for clarity. $\times 27.5$.

the anterior caudal haemals are specialized in the male. Also the total number of caudal vertebrae is identical in the males and females. But in the adult males the anterior two caudal haemals are specialized. Each is a long heavy bone slanting in an anterior direction as far as the dorsal ends of the interhaemals. As in *Lebistes*, paired pointed projections extend posteriorly from the lateral sides of the closed haemal arch and can overlap the next posterior haemal process. No caudal haemal specialization can be found in the young up to nine weeks of age and material between this age and adults is not at hand.

3. *Gambusia holbrooki* (Girard).

(Text-figs. 12-14).

Diagnostic Characters:

Caudal fin count usually $\frac{12, 12, 13.}{13 \quad 14 \quad 13}$

Caudal raylets extend anteriorly to approximately the third posterior neural and haemal spines.

Modification of anterior three caudal vertebrae in male. Anal fin in male specialized in this viviparous species.

4 posterior neurals and haemals elongated into the caudal contour.

Vertebral count: 13 trunk, plus 18 to 20 caudal. Total 31 to 33.

1 epural.

1 large fan-shaped hypural and 1 slender hypural.

Median hypural not completely divided in mid-line.

Material Studied.

<i>Length.</i>	<i>KOH Cat. No.</i>	<i>Text-fig. No.</i>
(25) Males 16-25 mm.	2225	
(27) Females 15-31 mm.	2225	12
(12) Embryos 5 mm.	2225A	13
(6) Dissected male haemals	2225	14

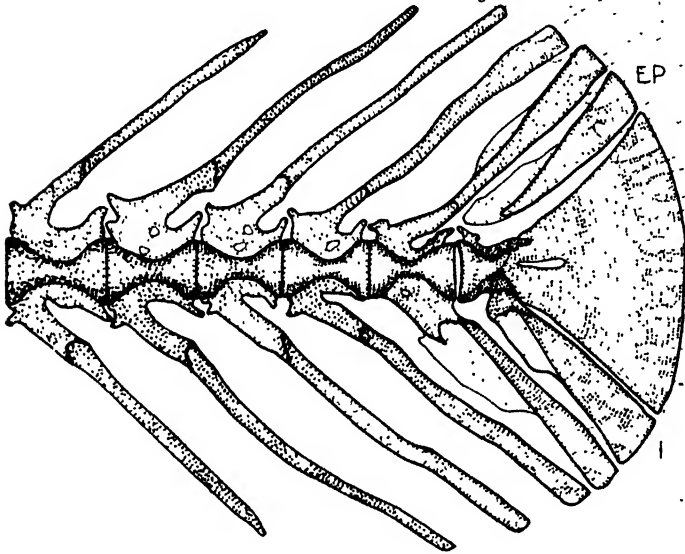
Caudal Osteology.

Urostyle: The urostyle is almost a perfect half centrum and conical in shape. The posterior tip is blunt and upturned and can be seen in most specimens at the base of the fan-shaped hypural. No separate segments of the urostyle can be found even in the 5 mm. embryos. In these young specimens the upturned tip of the urostyle is less reduced and proportionately larger than in the full-grown fish. In both the embryos and adults the urostyle appears consolidated with the median hypural. In embryos and adults either one or two reduced neurals are present on the urostyle.

Uroneurals: There is no trace of uroneurals in any of the specimens.

Hypurals: There are two hypurals present in all specimens both embryo and adult. The large median hypural is fan-shaped and approximately five and a half times broader on the distal margin than the ventral hypural. The larger hypural supports about ten caudal rays. In all but a few of the specimens there is a median slit near the base of the large hypural. The distance that this opening extends posteriorly is variable and cannot be correlated with sex or age. In one of the embryos and two adults a delicate line is seen with the high power lens which extends through the anterior base of the hypurals to the slit-opening. The study of younger embryos might determine whether or not this large hypural is at one time definitely divided.

But in none of the specimens is there any indication of a division of the distal part of the hypural. Considerable ossification exists in the caudal region of the young of these ovoviviparous embryos. The smaller hypural is entirely ventral in position. The bases of the two lateral sides, comparable to the haemal arches in the anterior processes, overlap the base of the larger hypural. In all of our specimens there is variation in the size and details of the shape of these haemal bases.



Text-figure 12.

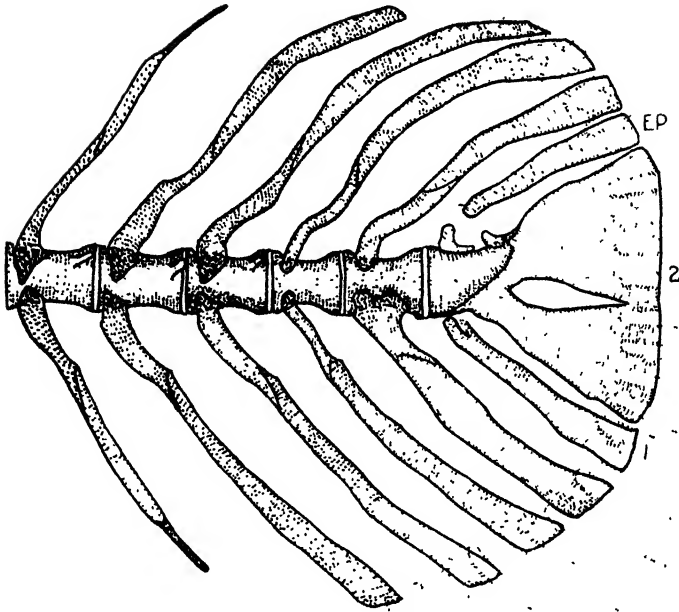
Gambusia holbrooki. Adult female, length 28 mm. This caudal represents a typical adult male and female. The single fan-shaped hypural is characteristic of this species. \ 20.84.

Epural: There is one epural in all specimens. This bone is similar in shape and position to the corresponding element, the ventral hypural, and the two flank respectively the anterior ventral and anterior dorsal surfaces of the median fan-shaped hypural. Similar to the hypural, the basal end of the epural varies in exact position in the different specimens.

Caudal Fin Ray Count:

$$\begin{array}{r} 2 \text{ or } 3 + 10 = 12 \text{ or } 13. \\ 3 + 10 \text{ or } 11 \quad 13 \text{ or } 14 \end{array}$$

Additional Characters Worthy of Note: The total number of caudal vertebrae is identical in the males and females of this series of *Gambusia holbrooki*. But in the males the three anterior caudal haemals are highly specialized. Each one is relatively large and dagger-shaped with the tips of the spines directed anteriorly as far as the dorsal ends of the interhaemal spines. Extending posteriorly from the region of the closed haemal arches are paired projections which are capable of overlapping the next posterior



Text-figure 13.

Gambusia holbrooki. Embryo, length 5 mm. There is considerable ossification in the caudal area but not in the head region. The column is unsegmented and the centra not spool-shaped as in the adult. The fan-shaped hypural shows no indication of separate elements. $\times 86.84$.

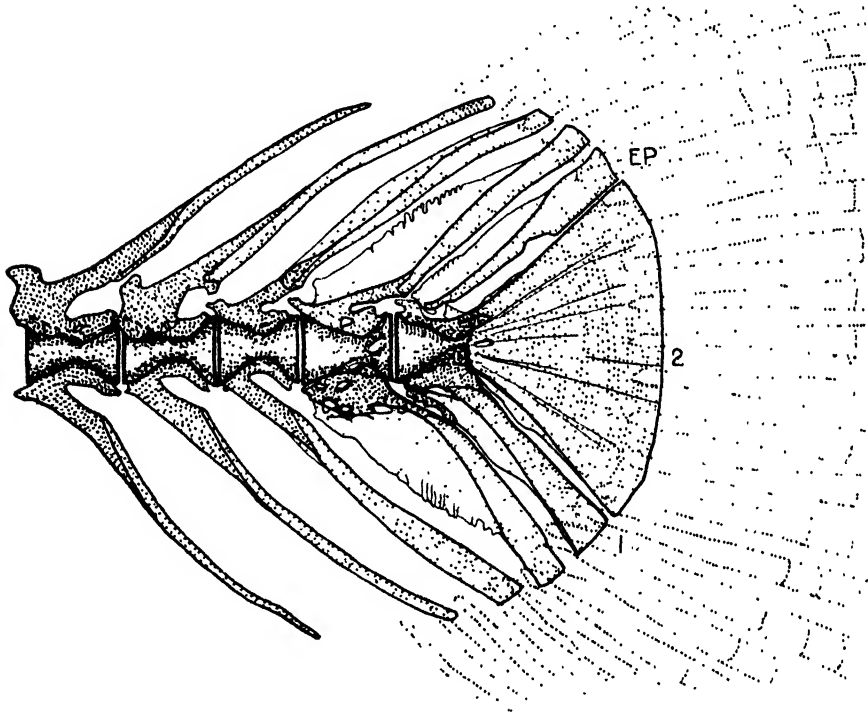
haemal process. For description of the mechanical functioning of these specialized male haemals see Collier's⁴ splendid article on *Gambusia afinis afinis* (Baird & Girard). In comparing the detailed drawings of both the total skeleton and the specialized haemals of this species with the specialized haemals in our *Gambusia holbrooki*,⁵ it is conspicuous that the anterior, or first, caudal of *Gambusia afinis afinis* is more slender and simple than that of *holbrooki*. It is to be assumed that Collier's illustrations are typical, and so this difference may be found to be a definite caudal character in the two species. No male caudal specialization can be determined in the twelve embryos. In the smallest adult males, (16 mm.), the anterior caudal haemals are differentiated but small, and the general appearance of the anal fin is like that of the young females. Although we lack stages between the 5 mm. embryos and the 16 mm. specimens, it would seem that the development of the specialized caudal haemals probably commences at approximately this latter age, and earlier than the development of the prolonged stout third anal ray characteristic of the adult male. In all specimens but two, up to 20 mm. long, there is no marked development of this ray which is, on very

⁴ Collier, Albert, 1936. The Mechanism of Internal Fertilization in *Gambusia*. Copeia, No. 1, May 10, 1936.

⁵ Langer, W. Fr., 1913. Beiträge zur Morphologie der viviparen Cyprinodontiden. Morphologisches Jahrbuch, 1913, vol. 47. pp. 193-307. 150 figs., 244 bibliographical references. Illustration of the specialized haemals in the male *Gambusia holbrooki*.

Caudal Osteology.

Urostyle: The slender upturned end of the urostyle can be seen in most of the specimens in the base of the large hypural. No separate segments can be found either in the 6 mm. embryo or the 6, 8 and 10 mm. young. In these small specimens the upturned end of the urostyle is proportionally larger and longer than in the adult fish. The urostyle and the base of the large hypural appear consolidated in specimens of all sizes. Reduced paired neurals are present on the urostyle in all specimens and there is variation in their size and shape.



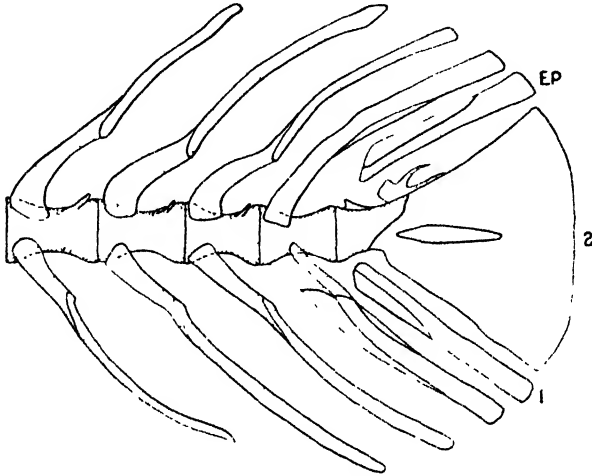
Text-figure 15.

Lebistes reticulatus. Adult female, length 28 mm. This caudal represents a typical adult male and female with the exception of the irregular lines on the second hypural. The growth lines in the large hypurals are not present in the young or the males. $\times 16.9$.

Uroneurals: There is no trace of uroneurals in our specimens.

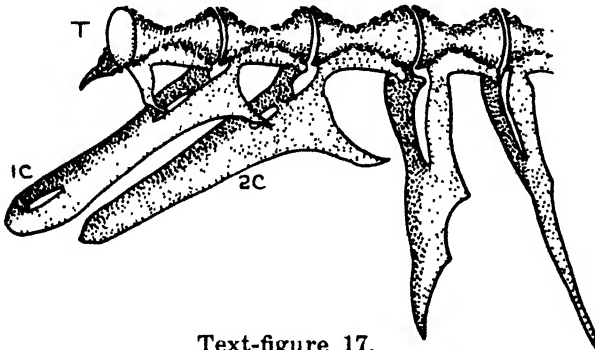
Hypurals: There are two hypurals present in young and adult specimens of all lengths. The large hypural is fan-shaped and median in position and approximately nine times broader on the distal margin than the other ventral hypural. The larger hypural supports approximately ten caudal rays. In most specimens there is a median slit in the basal end of the larger hypural. The length varies in the different specimens and cannot be associated with sex or age. In one embryo a faint line is present extending from the anterior end of the slit through the base of the hypural, but there is no line through the distal end of the hypural to indicate two distinct bones. Because of negligible evidence the larger hypural is considered a single structure. In most of the large females lines of various lengths are present radiating from the base of the large hypural toward the distal margin. These are not seen

in the young. There is considerable ossification in the caudal region of the embryos of this viviparous species. The second and smaller hypural is ventral in position and the basal part of the two lateral sides overlap part of the larger hypural near the urostyle. There is a thin wing of bone in the adults extending almost the full length of the anterior side of the hypural. This varies in length and shape in all specimens.



Text-figure 16.

Lebistes reticulatus. 1 day old, length 6 mm. Delicate ossification is present in the caudal area and considerably less in the head region. The distal tips of the spines and hypurals are unossified and the column is unsegmented. $\times 66.3$.



Text-figure 17.

Lebistes reticulatus. Anterior caudal haemals of adult male, length 18 mm. Shows the last trunk process and the two anterior caudal haemal processes specialized in the male. The first caudal spine has an opening for the insertion of the dorsal ends of the posterior interhaemals. The ribs and the neurals have been omitted for clarity. $\times 25$.

Epural: There is a single epural in all specimens. This bone resembles its counterpart, the smaller hypural, in shape and size.

Caudal Fin Ray Count:

$$\frac{3 + 9}{4 + 9}, \frac{2 + 10}{3 + 10}, \frac{3 + 10}{3 + 10} = \frac{12}{13}, \frac{13}{13}$$

Additional Characters Worthy of Note: As in *Gambusia*, the anterior caudal haemals are specialized in the male. The total number of caudal vertebrae is identical in the males and females of this collection of *Lebistes reticulatus*. But in the adult males, the anterior two caudal haemals are specialized. Each one is a long heavy bone and slants in a ventral and anterior direction as far as the dorsal ends of the interhaemals. Paired, pointed projections extend posteriorly from the lateral sides of the closed haemal arch and are capable of overlapping the next posterior haemal process. No male caudal haemal specialization can be found in the embryos and young specimens, and the anal fin shows no specialization in any of these young fish up to 12 mm. But in the smallest of the adult males, 13 mm., both caudal haemals and anal fins are completely developed.

No gross structural differences can be found in the six young, two and a half months old, which were the second generation reared in sea water.⁶

SUMMARY.

The following facts correlate the salient similarities found in the study of Bermuda Cyprinodontes.

Caudal fin count: *Fundulus* has more raylets than the poecilids: *Mollienisia*, *Gambusia*, *Lebistes*. The total count is increased in *Fundulus* by the greater number of raylets. The total count, less raylets, is nearly the same in the four species.

Caudal raylets extend anteriorly to approximately the fifth posterior neural and haemal in *Fundulus* but in the three species of poecilids the caudal raylets only extend to about the third posterior neural and haemal spines. In *Mollienisia* subspecies there is an increase in the raylets and along with this an additional neural and haemal is prolonged into the caudal contour.

Fundulus is oviparous and there is no modification of the ventral haemals in the male. The anal fin in the male and female is similar in *Fundulus*.

The poecilids are viviparous and there is modification of the ventral caudal haemals in the male, 2 in *Mollienisia* and *Lebistes*, with an opening in the tip of the first spine for the insertion of the posterior interhaemals, and 3 in *Gambusia* with no opening in the tip of the first spine.

In *Fundulus* the 5 posterior neural and haemal spines are elongated to the margin of the caudal contour. In *Mollienisia sphenops* 3 posterior spines are elongated and in *Mollienisia sphenops* subspecies, in most specimens examined, 4 posterior spines. In *Gambusia* and *Lebistes* 4 posterior spines are elongated.

Vertebral count: The total number of trunk vertebrae in the four species is almost the same. *Fundulus* 12-14, *Mollienisia* 12, *Gambusia* 13, *Lebistes* 12. The total number of caudal vertebrae is more variable, *Fundulus* having 19-21, *Mollienisia* 16-18, *Gambusia* 18-20, *Lebistes* 14-17.

All four species have 1 epural.

Fundulus, *Gambusia* and *Lebistes* have 2 hypurals—1 large fan-shaped hypural and 1 slender hypural. *Mollienisia sphenops* has 3 hypurals, 2 large and 1 slender bone. No separate elements can be found in the urostyle of any specimens of the four species studied.

⁶Hollister, 1924. Salt and Fresh Water Viability of Fish.

10.

The Histology of the Eye of the Cave Characin, *Anoptichthys*.

E. B. GRESSER & C. M. BREDER, JR.

*Department of Ophthalmology, New York University College of Medicine,
New York Aquarium.*

(Plates I-III).

INTRODUCTION.

The blind cave characin, *Anoptichthys jordani* Hubbs & Innes, described in 1936, represents the first of the order Heterognathi to show loss of ocular structure. The Eventognathi and Nematognathi both long have been known to have cave representatives with defective or absent vision. Since cave fishes are not exactly numerous nor spread through many of the orders of fishes, it is interesting to find species in each of the major divisions of the Ostariophysi. In a list presented by Hubbs (1938) in which he names all blind fishes and cave fishes, whether blind or not, exclusive of deep sea forms, 20 belong to the Ostariophysi, while all the rest contribute only 27. Of the former, 19 are derived from barbeled forms, and, as Hubbs points out, this may well have to do with their relatively numerous presence in caves.

EYE STRUCTURE.

The eyes of *Anoptichthys jordani* are somewhat translucent and depressed below the surface of the ectoderm. A pigment layer is apparent by direct examination, this layer forming, as far as is evident by the eye, a cyst wall without an anterior opening.¹ As will be shown later, this is evidenced microscopically to be an intact cyst without a pupillary space.

In a fish 56 mm. long, the gross measurements of the optic organ are 1.5 mm. vertically, 1.5 mm. horizontally, and 1.2 mm. antero-posteriorly. The eye is definitely below the level of the skin and is over-lapped by folds of epidermis which in some specimens continue inwardly to form a solid stalk of epithelial tissue and in others an invagination of epithelium forming a blind sac. In both formations the epithelial column is directly in contact with a solid mass of condensed mesodermal tissue corresponding to the cornea. The attachment of this epithelial column to the corneal layers is within the corneal surface area and not beyond. Intervening from all sides around the stalk is a loose mesenchymal structure.

In general the eye has recognizable definitive layers, although of poor development. The external musculature is present and an optic nerve has an outline. The primitive optic vesicle without question has undergone its first invagination and at this level apparently ceased to differentiate beyond a pigment layer and a retinal layer. At this point it may be well to acknowledge that evidence set forth below shows the primary vesicle after its invagination to be definite in character by the presence of the pigment

¹ The distal portion of the eye is here referred to as anterior.

epithelium and several layers of retinal elements, although there has taken place a degenerative change in which the edges of the vesicle have fused, with poor attempts at the formation of a rod and cone layer and absence of an outer nuclear layer. It is conjectural at this stage of development whether the force—genetic, hormonal or intracellular metabolic control—has failed to stimulate the overlying epithelial cells to the formation of lenticular tissue, or perhaps the epidermal column does represent this attempt and is shown by its failure to progress beyond the stage of forming a secondary vesicle. Whatever the answer may be, whether the eye stops in development because no lens develops and produces in turn the fusion of the poorly differentiated primary vesicle into a cyst, or vice versa, the eye has not progressed to any stage wherein vision can be served.

The cartilaginous-walled orbital cavity contains six extraocular muscles that probably are functionally useless, judging from the weak striations in the fibers.

The outer mesodermal layers are the best developed, a well marked cartilaginous sclera, cup-shaped as is characteristic of piscine eyes, with a posterior aperture for the entrance of an optic nerve and anteriorly replaced by a laminated translucent fibrous tunic representing the interstitial tissue of the cornea. It is apparent from what has been said above that the primary vesicle, although differentiated and invaginated, still forms a complete cyst, thereby precluding the presence of a pupillary opening or permitting the development of iris tissue as such. Some basis, however, for the possible formation of iris tissue is present, as is evident by the pigment epithelium and in addition the extension of a layer of small blood vessels derived from the choroidal network. Between this layer and the interstitial mesoderm of the corneal analogue there is a solid mass of large, light-staining cells with a faint amount of chromatin material, mesenchymal in appearance, that is present in all the eyes examined. It is probable that this is a primitive tissue of supporting nature that would have disappeared if the eye had progressed to maturity. In an occasional eye, not in every one examined, there has been seen a well-defined cleft, unfilled with cells, that stimulates the imagination to conceive it as a possible anterior chamber, inasmuch as it possesses a definite single layer of flat lining cells.

The choroidal layer is as well defined as the sclera. A definite choroidal gland is present, with its system of blood vessels, and warrants no further description.

The retinal pigment epithelium is the best-defined of the retinal layers and throughout is a layer of irregular hexagonal cells within which are massed brown melanin pigment granules. This layer, the outer part of the optic vesicle and without question continuous with the layer of nerve elements on its inner surface, does not contain a space between the borders of invagination but is apposed to its opposite side, forming a complete cyst. In several of the eyes examined there has been further growth of the wall of the optic vesicle with the formation of subsidiary cysts within the main body, each lined with an aborted type of retina. Of the usual stratification of the retina that is discernible, the inner nerve fiber layer is weak and thin throughout, even at the entrance of the optic nerve where it might be expected to have a thickness of fibers. The ganglion cell layer is in the main a single layer of cells which is neither continuous throughout nor well developed. The inner plexiform layer is found without obvious defects in its architecture. The inner nuclear layer is definite but lacks structural delineation in its finer distribution and in the quality of its clear arrangements. The outer plexiform layer or network is weak and thin. Both the outer nuclear layer and the layer of rods and cones show the poorest attempts at development. Where the one fraction of a tissue such as the rods or cones is not to be found, it is evident that their nuclear parts would be absent. It is not possible either from our material or present knowledge to state upon which deficiency is predicated the non-development of the elements. In sev-

eral areas, islands of rods with small nuclei are found, but in which no sign of a limiting membrane between the two parts is seen. Another frequency are areas or islands of embryonal retinal cells that have a pigment mantle but cannot be differentiated as to type. The abortive attempts to form rods or cones are usually found in the more peripheral parts of the cyst wall.

Only at the center of the vesicle is there any evidence of a vitreous body. The retinal tissue cyst walls in most areas are apposed and only at the mid-part are slightly separated by a faint, loose syncytium of cells representing a vitreous mass. This tissue, in turn, has nuclear elements in a faintly granular cytoplasmic matrix that stains faintly with hemotoxylin, a primitive type of vitreous.

The optic nerve has not been separated into fascicles and no intraneural bundle supporting framework has been noted. Scattered throughout the nerve stalk are large, faintly basophilic nuclei containing fine, granular material. They are mainly round, evidently nuclei of nerve cells. Their appearance and their faint cytoplasmic prolongations, which are quickly lost, suggest a nerve cell of embryonic character. Nerve fibers are few in the stalk and poorly developed.

DISCUSSION.

A prime step in any attempt to understand the nature of these peculiarities would seem to be to determine, if possible, whether these changes are degenerative in each fish or whether they are in the nature of an arrested development. The foregoing descriptive matter would seem to indicate clearly that this species lacks vision because of a stoppage in development of the eye structures at an early stage rather than a cellular inactivity at a more advanced state.

Although we have not had very young specimens available, reports that they show more evident eye structure suggest, in the light of the foregoing, that the gross appearance of the young may be accounted for by the eye capsule being more visible from the exterior because of the thinner nature of the overlying tissue.

The more interesting question of whether the fish lost its visual equipment after entering cave waters or whether a mutation with defective vision simply found it possible to survive under such conditions, even today is a matter of speculation. An experimental approach would undoubtedly be of great value in this connection.

There is evident in the literature of blind vertebrates a marked tendency toward speculation, as is usual in cases where the evidence does not point very conclusively in any given direction. This centers about the significance of phylogenetic or ontogenetic factors, the entire subject of genetics in relation to mutations and about which came first—the cave environment or the blindness. Franz (1934) sums up the school of thought in which conditioning by darkness allegedly results in blindness by the acquired increments of steadily degenerating eyes both physically and physiologically, each generation adding its own amount of increment to the transmitted factor (or loss of factor).

Eigenmann (1900) in discussing the eye of *Amblyopsis*, also attributes the lack of ocular development to a genetic cause, based on comparison with *Forbesella (Chologaster) agassizii*, through the transmissibility of accumulated degenerative changes, stressing that the phylogenetic tendency is evident in the structural formation, although an irregular individual abirotrophy ensues almost at the start.

Since fishes living in regions of low light intensity are frequently provided with large eyes, and are found in association with a lesser number with reduced eyes, as in deep sea fishes, it should follow that at least some large-eyed forms should be found in cave environments as representing a stage in the gradual accommodation to life without light at all. Actually no

such condition has been found in those forms that are true cave dwellers. Hubbs (1938) describes a new subspecies of *Cichlasoma urophthalmus*, *C. u. ericymba*, as having a very slightly larger eye than the other subspecies of this form. These fish are, moreover, apparently not true cave fishes but occupy the more or less open cenotes of Yucatan and the difference in eye size noted by him may have nothing to do with their habitat, especially since the variation is not nearly as great as that frequently found among closely related fishes living in open waters, and also as the Cichlidae have not produced a single blind cave form. The pigment of this fish is only slightly reduced, but more striking is the unusual development of the sensory pores about the head.

The view, on the other hand, that posits a chance mutant form with an accidental association with a cave, as is discussed by Hubbs, would seem more reasonable in the light of modern evolutionary thought. Genetic experiments crossing *Anoptichthys* with *Astyanax*, rearing several generations of *Anoptichthys* in light, an examination of the food intake of wild fish from the caves, and an assay of their vitamin A content, should go far to elucidate the concepts involved. Until at least some of these are undertaken, it would seem to be pointless to attempt further speculation.

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EXPLANATION OF THE PLATES.

(Photomicrographs by Dr. R. F. Nigrelli)

PLATE I.

- Fig. 1. *Anoptichthys jordani*. Mid-vertical section; ocular layers differentiated but underdeveloped, except sclera and choroid. Note absence of iris, pupil, anterior chamber and crystalline lens.

PLATE II.

- Fig. 2. *Anoptichthys jordani*. Mid-horizontal section. Retina lacks normal architectonics; pigment epithelium fused, forming vesicle.

PLATE III.

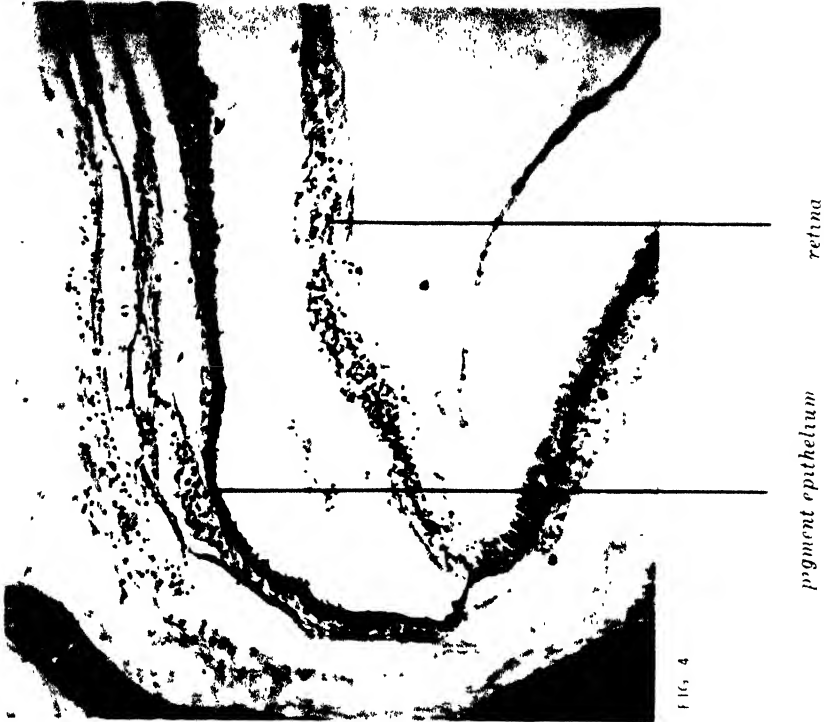
- Fig. 3. *Anoptichthys jordani*. Horizontal section at periphery. Retinal vesicle subdivided into two cystic spaces. An epithelial stalk connects the sub-surface eye with epithelial surface.
- Fig. 4. *Anoptichthys jordani*. Retinal pigment epithelium of normal appearance; retina lacks rods and cones, and lamination of plexiform and ganglion cell layer.





FIG. 2

THE HISTOLOGY OF THE EYE STRUCTURE OF THE CAVE CHARACIN, ANOPTICHTHYS.



THE HISTOLOGY OF THE EYE STRUCTURE OF THE CAVE CHARACIN, ANOPTICHTHYS

11.

Plankton of the Bermuda Oceanographic Expeditions. IX.
The Bathypelagic Caridean Crustacea.¹

FENNER A. CHACE, JR.

Assistant Curator of Marine Invertebrates, Museum of
Comparative Zoology, Harvard University

(Text-figures 1-64).

CONTENTS.

	Page	Page
Introduction	117	<i>Notostomus robustus</i> 168
Systematic Discussion	119	<i>Notostomus perlatus</i> " 170
Key to the Bermudian Families of Bathypelagic Caridea	121	<i>Notostomus westergreni</i> 171
Family Pasiphaeidae	121	Genus <i>Ephyrina</i> 172
Genus <i>Pasiphaea</i>	122	<i>Ephyrina hoskynii</i> 173
<i>Pasiphaea hocerca</i> , sp. nov.	122	<i>Ephyrina bifida</i> 174
<i>Pasiphaea hoplocerca</i> , sp. nov.	124	Genus <i>Hymenodora</i> 175
Genus <i>Parapasiphaea</i>	126	<i>Hymenodora gracilis</i> 175
<i>Parapasiphaea sulcatifrons</i>	126	Genus <i>Systellaspis</i> 179
<i>Parapasiphaea macrodactyla</i>	128	<i>Systellaspis braueri</i> 180
<i>Parapasiphaea</i> , sp. a	129	<i>Systellaspis debilis</i> 181
<i>Parapasiphaea</i> , sp. b	130	Genus <i>Oplophorus</i> 184
Genus <i>Leptochela</i>	131	<i>Oplophorus spinicauda</i> 184
<i>Leptochela bermudensis</i>	131	<i>Oplophorus grimaldi</i> 187
Family Oplophoridae	132	Family Bresiliidae 189
Genus <i>Acanthephyra</i>	133	Genus <i>Lucaya</i> 189
<i>Acanthephyra purpurea</i>	134	<i>Lucaya bigelowi</i> 189
<i>Acanthephyra haeckelii</i>	140	Family Pandalidae 190
<i>Acanthephyra curtirostris</i>	143	Genus <i>Plesionika</i> 190
<i>Acanthephyra stylorostrata</i>	144	<i>Plesionika martia</i> 190
<i>Acanthephyra acutifrons</i>	146	Genus <i>Parapandalus</i> 192
<i>Acanthephyra ezimia</i>	147	<i>Parapandalus richardi</i> 192
<i>Acanthephyra brevisrostris</i>	148	Family Phytocoridae, fam. nov. 196
<i>Acanthephyra gracilipes</i> , sp. nov.	149	Genus <i>Phytocaris</i> , gen. nov. 196
<i>Acanthephyra</i> , sp. ?	151	<i>Phytocaris microphthalmus</i> , sp. nov. 196
Genus <i>Notostomus</i>	152	General Discussion and Summary 199
<i>Notostomus rescus</i>	153	Taxonomy 199
<i>Notostomus compes</i> , sp. nov.	156	Summary of Quantitative Results 200
<i>Notostomus marptochela</i> , sp. nov.	158	Geographical Distribution 201
<i>Notostomus miccylus</i> , sp. nov.	161	Color of Bathypelagic Caridea 203
<i>Notostomus mollis</i>	164	Luminescence 204
<i>Notostomus distirus</i> , sp. nov.	166	Food of Bathypelagic Caridea 205
		Bibliography 206

INTRODUCTION.

This report deals with the caridean decapod Crustacea taken during the course of the Bermuda Oceanographic Expeditions from 1929 to 1935 in a roughly circular area, eight miles in diameter, whose center is at 32° 12' north latitude and 64° 36' west longitude or nine and one-quarter miles south-southeast of Nonsuch Island, Bermuda. The total depth of water

¹ Contribution No. 597, Department of Tropical Research, New York Zoological Society.
Contribution from the Bermuda Biological Station for Research, Inc.

in this area increases from 1,000 fathoms at the inner rim of the circle to nearly 1,500 fathoms at the outer edge. Complete data on the 1574 nets towed will be found in Beebe (1931, 1932 and 1936).

Inasmuch as open nets were employed throughout these investigations, any precise distributional evidence disclosed by the collection must be accepted with some reserve. Nets usually were towed, six at a time, at 100 fathom intervals, and the towing time began when all six nets reached their designated depth and ended when the nets started to come up from that level. Nets towed at the deeper levels, therefore, were actually fishing a good deal longer than the time given and the catches from these deeper hauls should be somewhat greater proportionately than those made by the shallower tows. Although it was convenient to use as a quantitative unit the average number of specimens taken by a one meter net in one hour of towing, it is evident that this figure probably never represents the actual number of specimens per towing hour at any one level or in any one month, and it should be used with caution when comparing the relative abundance of species of bathypelagic Caridea in the Bermuda area with those taken elsewhere by other expeditions. Since this figure does not mean exactly the same at different levels, its use in computing the relative abundance of a species at different depths fails to give a perfectly true picture of existing conditions. However, although it varies with the depth, the number of specimens per towing hour can be used as a basis for comparing the relative abundance of different species at each level and distribution graphs for different species based on this unit can be compared directly with little fear of distortion of fact.

Most of the material which forms the basis of this report was taken in 1929, 1930 and 1931; the great majority of the tows made after 1931 were surface hauls and contained no adult Caridea. Since all but one series of the deep water nets were towed in the daytime—most of them in the morning—the collection fails to yield much data on the diurnal migrations of these animals; I have seen no specimens taken in Nets 224 to 229 which were towed at night between 500 and 1,000 fathoms. In general, specimens from several nets from the same level were put together, but in 1929 and 1930 these combined hauls seldom represented a period of more than two or three weeks and a rough idea of the seasonal distribution of each species could be obtained. In 1931, however, tows as much as six to eight weeks apart were put in the same container so that it was found impractical to derive any seasonal distribution data from this 1931 material.

After taking all of these factors into consideration, it was felt that the greatest value in the collection was its completeness. This, the first extensive expedition to devote its resources to the investigation of the deep water fauna of a relatively small column of water, accumulated such a vast amount of material that it is unlikely that future work in the Bermuda area will find many forms not represented in this collection unless they be extremely rare or accidental strays from another oceanic area. In the belief that the Bermudas offer an ideal base for oceanographic exploration and, therefore, that more and more work of this nature will be carried on there in the future, it seemed advisable to make of this report a guide to the identification of the bathypelagic caridean prawns of the Bermudian region. The known geographical distribution of many of the species indicates that the fauna is representative of a large part, if not all, of the Sargasso Sea area as well, and the report may therefore serve as a supplement to the excellent guide to the more northern forms of the North Atlantic to be found in Kemp, 1910.

Wherever practical the figures have been made from Bermuda specimens. In the few cases where it has been necessary to copy previously published figures, due acknowledgment is given. Among the references dealing with each species an attempt has been made to include, besides the reference to the original description, all synonyms and one of the best recent references from which a complete list of authors may be traced. The bibliography, in

the main, is made up only of those works to which reference is made in the text, but these include most of the important papers dealing with bathypelagic Caridea published to date.

This opportunity is taken to express my gratitude to those who have assisted in this report. First, I wish to thank Dr. William Beebe for entrusting this unique collection to me and for supplying valuable notes from life on certain of the prawns. Dr. Stanley Kemp has been most helpful in solving several perplexing problems both by sharing his wealth of carcinological knowledge and by supplying specimens for direct comparison. Dr. Robert Gurney, as an expert on larval development, has been ever willing to lend his aid in verifying or refuting certain conclusions. Mr. John C. Armstrong, of the American Museum of Natural History, offered many helpful suggestions on methods of attacking the quantitative aspects of the report while engaged in postgraduate work at the Museum of Comparative Zoology. My deepest thanks go to Miss Jocelyn Crane of the Department of Tropical Research of the New York Zoological Society. Miss Crane has most generously turned over to me copious notes made from life on many of the prawns—color notes, notes on luminescence, activity and feeding—which add immeasurably to the value of the report; all such remarks on color and other aspects of the living animal, unless otherwise credited, have been taken from Miss Crane's notes. I wish to express my sincere gratitude to Mr. M. D. Burkenroad of the Bingham Oceanographic Foundation at Yale University for the great amount of valuable time he gave up to sorting out this material and sending it on to me. Acknowledgment is also hereby made of the kindness of the Secretary of the Smithsonian Institution in permitting mention to be made of specimens of certain species of Ophiophoridae in the collections of the U. S. National Museum.

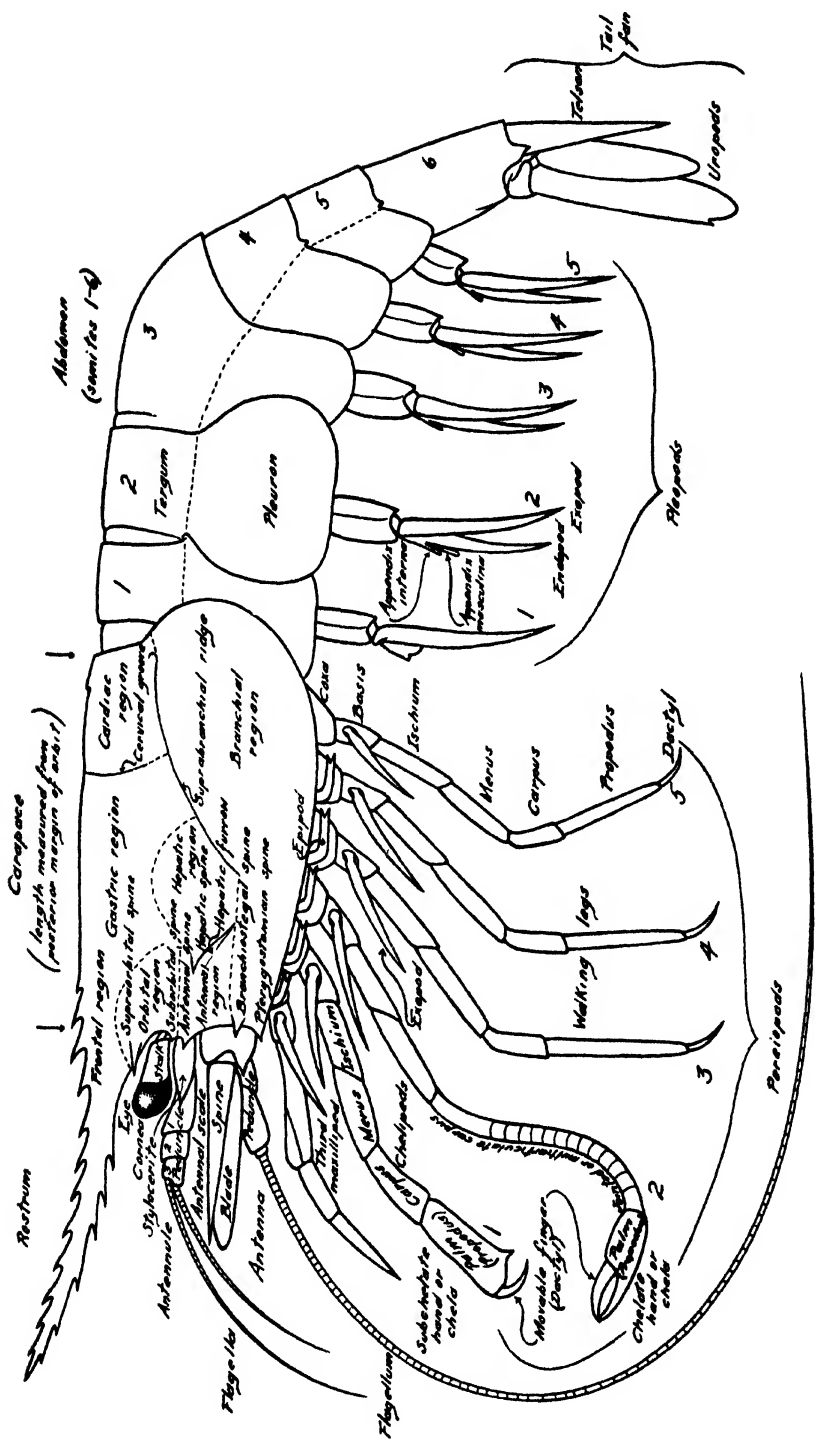
It is unfortunate that lack of time prevents a more complete investigation of certain aspects of this collection. When there is insufficient time to cover all angles of a study such as this, it is only natural that only those phases of greatest interest to the individual worker are treated. It is therefore with the realization that the possibilities of the present collection are far from exhausted that this report is submitted, and it is hoped that the few problems brought to light may lead to further investigations of a similar nature.

SYSTEMATIC DISCUSSION.

The Caridea form one of the tribes of the most primitive suborder of the Decapoda, the Natantia or the shrimps and prawns. The suborder is divided into three tribes; the Penaeidea, the Caridea and the Stenopidea. The Caridea are characterized by usually having the abdomen more or less sharply bent at the third somite, the pleura of the second abdominal somite overlapping those of the first, the first maxillipeds with a lobe at the base of the exopod, the third maxillipeds composed of from four to six joints—not seven, the third pereopods never chelate and the gills phyllobranchiate. The simplest and most useful character for distinguishing carideans at a glance is the overlapping of the first abdominal pleuron by the second.

Text-fig. 1 is a diagram of an ideal caridean showing the more important structures. An attempt has been made to employ the simplest terms in common usage where there is no confusion as to their meaning.

The standard measurement used is the carapace length, measured from the posterior margin to the hind margin of the orbit. Although this procedure has its disadvantages in that it fails to give a clear idea of the entire size of the animal and the ratio of carapace length to abdomen is not always constant, it is far more accurate in general than the total length. In most Caridea it is extremely difficult to extend the abdomen to its greatest length after the specimen has been in preservative for any length of time, and the



Text-figure 1.
Lateral view of a caridean prawn (in part after Schmitt, 1921).

length of the rostrum varies so much from one species to another that its inclusion in the measurement only leads to greater confusion.

As a standard size in comparing one species with another it has been found convenient to use the carapace length of young males in which the appendix masculina has not attained its full length. It is found that this appendix grows so rapidly that the carapace seldom increases more than a millimeter in length from the time the appendix first appears until it attains its full growth. The stage at which the appendix first appears also is remarkably constant in specimens from one locality; whether a different environment affects the size of the prawn at this stage remains to be seen. Although the size of the smallest egg-bearing female may more nearly define the actual size of the animal at maturity, a long series of specimens is necessary to determine this measurement, whereas a single young male will yield a fairly accurate standard figure by the first method.

It is nearly impossible to make any definite rule for the determination of sex in Caridea. In general, the safest procedure is to look for the appendix masculina on the inner margin of the endopod of the second pleopods. In the Oplophoridae, the family to which the greatest number of bathypelagic species belong, the endopod of the first pleopods is usually sexually modified so that this character is frequently easier to use when one becomes familiar with its form in both sexes. There are certain species however, scattered among several families, in which there is no appendix masculina in the male and the endopod of the first pleopod fails to show any clear sexual dimorphism; in such instances the abdominal pleura are usually modified in one sex, but familiarity with the form in each species is necessary in order to distinguish the sexes in these species.

KEY TO THE BERMUDIAN FAMILIES OF BATHYPELAGIC CARIDEA.

1. Exopods present on some or all pereiopods; first two pairs of pereiopods obviously chelate; second pereiopods with an undivided carpus 2
 No exopods on any pereiopods; first pereiopods either simple or microscopically chelate; second pereiopods with a segmented carpus 4
2. First two pairs of pereiopods much longer and stouter than last three pairs *Pasiphaeidae*
 First two pairs of pereiopods shorter than last three pairs 3
3. Third abdominal somite not produced as a broad cap over the fourth somite; mandibles imperfectly cleft *Oplophoridae*
 Third abdominal somite produced as a broad cap over the fourth somite; mandibles distinctly cleft *Bresiliidae*
4. Integument firm; carapace not inflated; mandibles deeply cleft with a three-jointed palp *Pandalidae*
 Integument thin and fragile; carapace inflated; mandibles without incisor process or palp *Physetocaridae*

Family Pasiphaeidae.

Rostrum short or absent; in the latter case it is represented by a post-frontal gastric spine. First two pairs of pereiopods chelate, much longer and stouter than last three pairs, and with the carpus undivided. Exopods present on all pereiopods, much reduced or absent on second maxillipeds. Terminal joint of second maxillipeds normal, not applied as a strip to the end of the preceding joint. Mandibles without a molar process and with or without a palp.

KEY TO THE BERMUDIAN GENERA OF PASIPHAEIDAE.

1. Fourth pereopod much shorter than either third or fifth; size medium or large, adults more than two inches long 2
 Last three pereopods progressively diminishing in length from the third to the fifth; size small, less than an inch in length; rostrum arising from frontal margin; mandible with a one-jointed palp *Leptochela*
2. Rostrum in the form of a post-frontal spine; mandible without a palp *Pasiphaea*
 Rostrum arising from the frontal margin; mandible with a two-jointed palp *Parapasiphaea*

Genus *Pasiphaea* Savigny, 1816.

Rostrum represented by a post-frontal gastric spine. Orbits poorly defined. Fourth pereopod shorter than fifth. Mandible without a palp.

KEY TO ADULTS OF THE BERMUDIAN SPECIES OF *Pasiphaea*.

- Carapace dorsally carinate; abdomen neither carinate nor dentate; fingers of chelae of second pereopods shorter than palm *P. liocerca*
- Carapace not dorsally carinate in posterior half; abdomen carinate on second to fifth somites and dentate on fourth to sixth; fingers of chelae of second pereopods longer than palm *P. hoplocerca*

Pasiphaea liocerca, sp. nov.

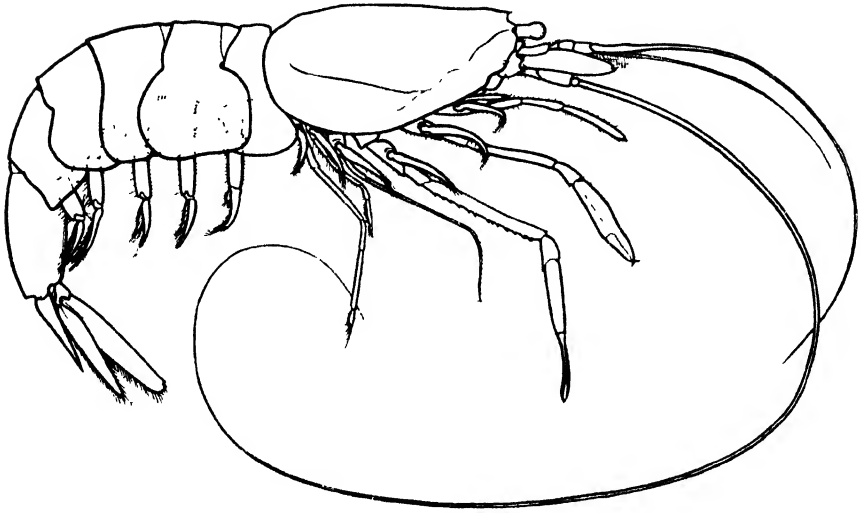
Text-figs. 2 and 3.

Type: Holotype ovigerous female, Cat. No. 31,1229, Department of Tropical Research, New York Zoological Society; Net 1160; August 10, 1931; 800 fathoms.

Diagnosis: Carapace dorsally carinate. Abdomen smooth, not carinate. Telson strongly forked. Gastric spine not attaining anterior margin of carapace. First pereopods unarmed. Fingers of chelae of second pereopods not longer than palm.

Description: Carapace dorsally carinate for nearly its entire length. Gastric tooth short, horizontal, falling short of the anterior margin of the carapace. Branchiostegal sinus obtuse, with a small submarginal spine anterior to it. Abdomen without a dorsal carina or armature on any somite. The sixth somite is strongly compressed near the dorsal margin, but still there is no trace of a carina. Telson sulcate for the entire length of its dorsal surface and terminating in a fork which is armed with 21 barbed spines. Eyes pale yellow in alcohol, without trace of an inner protuberance. Stylocerite spatulate and armed with a small terminal spine which falls far short of the end of the first antennular segment. Antennal scale convex along its outer margin and bearing a triangular terminal spine which projects but little beyond the end of the blade. There is a small spine on the antennal peduncle below the base of the scale. First pereopods without spines on any segment. The fingers of the first chelae are about two-thirds as long as the palm. Second pereopods armed with 11 to 13 spines on the merus and one spine at the lower angle of the carpus. The fingers of the second chelae are very slightly shorter than the palm.

Measurements: Total length about 46 mm.; length of carapace 14 mm. The eggs measure about 1.3 by 2.0 mm. in shorter and longer diameter.



Text-figure 2.

Pasiphaea liocerca. Holotype female. $\times 2.16$.

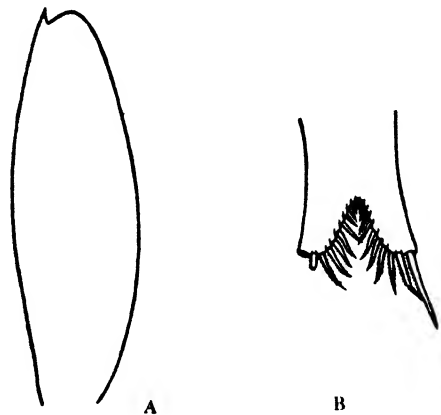
Color in Life: Body and appendages scarlet with the chelae and the tips of the pleopods deeper scarlet. Eyes bronze with golden centers. Eggs scarlet.

Remarks: The carinate carapace, smooth abdomen and strongly forked telson distinguish this species from all but five of the described species of *Pasiphaea*. Of these five, *P. longispina* Lenz, 1914, and *P. scotiae* (Stebbing, 1914) may be separated by the extremely long gastric spine; *P. alcocki* (Wood-Mason, 1891), *P. rathbunae* (Stebbing, 1914) and *P. corteziana* Rathbun, 1902, differ in having spines on the meri of the first pereiopods and the latter have the fingers of the second chelae distinctly longer than the palm.

In the present collection there are two young specimens of *Pasiphaea* which have been tentatively assigned to this species. Each has a carapace length of about 6.0 mm. One was taken in Net 63; May 3, 1929; 600 fathoms, and the other in Net 626 or 637; May 23 or 28, 1930; 500

Text-figure 3.

Pasiphaea liocerca. A. Antennal scale. B. Tip of telson.



fathoms. These specimens differ from the type of *P. liocerca* in having a slightly more pronounced gastric spine, no discernible dorsal carina on the posterior two-thirds of the carapace and only five spines on the merus of the second pereopods. Although the absence of a complete carina on the carapace and the small number of meral spines on the second pereopods would seem to ally these specimens more closely to the following species, the fact that the fingers of the second chelae are shorter than the palm very nearly precludes that possibility. Of these two species, *P. liocerca* and *P. hoplocerca*, the only representatives of the genus so far known from the Bermudian area, these young specimens are best accommodated in the first, and the differences noted between them and the type may well be due to their immaturity.

***Pasiphaea hoplocerca*, sp. nov.**

Text-figs. 4 and 5.

Types: Holotype female, Cat. No. 30,1688 Department of Tropical Research, New York Zoological Society; Nets 713, 753, 778; June-July, 1930; 700 fathoms.

One young; Net 22; April 15, 1929; 600 fathoms.

One young; Net 171; June 15, 1929; 600 fathoms.

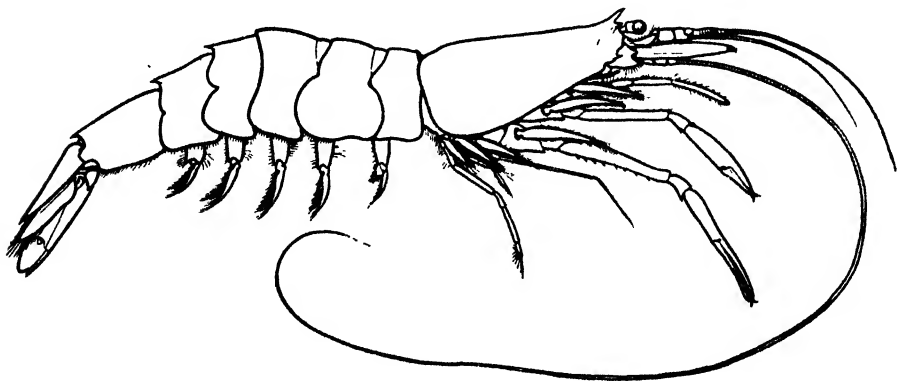
One female, one young; Net 195; June 20, 1929; 700 fathoms.

One young; Nets 199, 205, 217, 224, 232, 238 and 248; June 21-July 4, 1929; 500 fathoms.

One young; Nets 258, 264, 270, 276, 282 and 289; July 5-11, 1929; 900 fathoms.

Diagnosis: Carapace not sharply carinate dorsally behind gastric tooth. Abdomen carinate on second to fifth somites inclusive and dentate on fourth, fifth and sixth; telson strongly forked. Gastric spine reaching slightly beyond anterior margin of carapace. First pereopods unarmed except for a blunt tooth at lower end of basis; fingers of chelae of second pereopods much longer than palm.

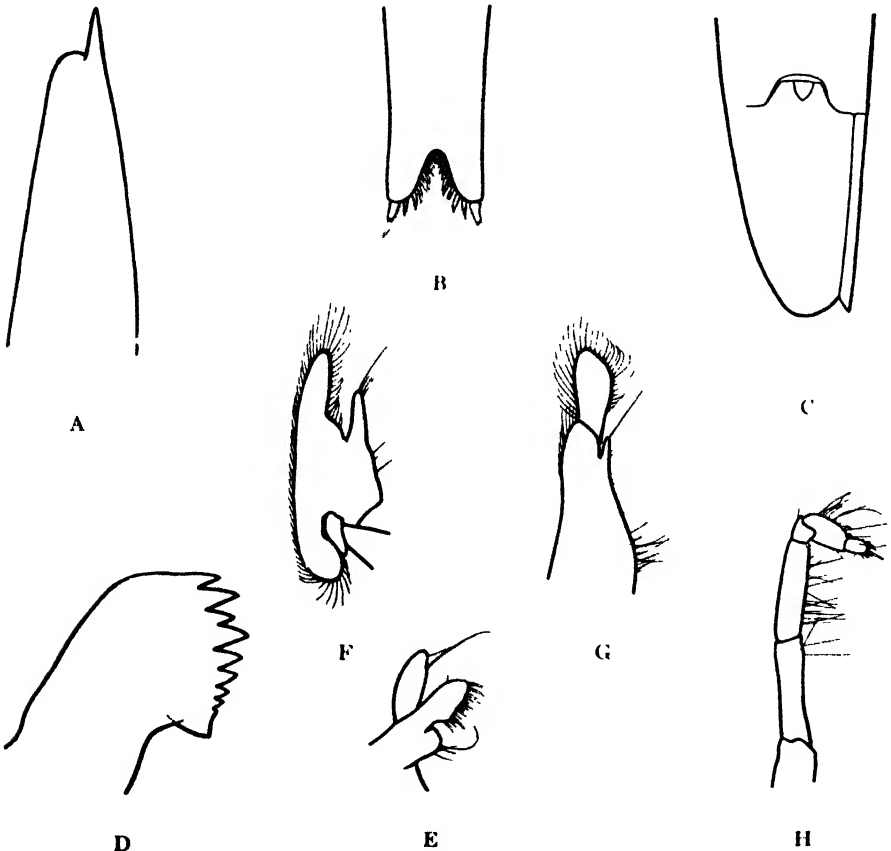
Description: Carapace not sharply carinate dorsally except on the strong gastric tooth which extends slightly beyond the anterior margin of the carapace. Behind this tooth a blunt carina extends backward along the dorsal mid-line and disappears at about the posterior fifth of the carapace. Branchiostegal sinus well marked, forming nearly a right angle.



Text-figure 4.

Pasiphaea hoplocerca. Holotype female. $\times 1.59$.

Anterior to this sinus is a strong branchiostegal spine arising from the margin of the carapace. On the lateral surface of the carapace, the supra-branchial ridge is obsolete; the only apparent ridges are a pair of short ones running backward from the orbital margin. Abdomen sharply carinate on the second, third, fourth and fifth somites and terminating in strong posterior teeth on the fourth, fifth and sixth. At the lower posterior angle of the sixth somite is a minute recurved spine which can be distinguished only with high magnification. Telson dorsally sulcate for nearly its entire length and forked at the end where it is armed with 21 barbed spines. Stylocerite reaches very slightly beyond the first segment of the antennular peduncle where it tapers to a point. There is a well marked spine on the antennal peduncle below the base of the scale. The latter bears a long outer spine reaching far beyond the end of the blade. Third maxillipeds do not extend quite as far as the tip of the antennal scale. First pereopods with a blunt tooth at the lower end of the basis and no spines on the merus or any other segments. Second pereopods with a similar basal tooth, merus armed with five to eight ventral spines and a single spine at the lower distal angle of the carpus. Fingers of the first chelae slightly shorter than the palm, those of the second one-fourth again as long as the palm.



Text-figure 5.

Pasiphaea hoplocerca. Paratype. **A.** Tip of antennal scale. **B.** Tip of telson. **C.** End of outer branch of uropods. **D.** Mandible. **E.** First maxilla. **F.** Second maxilla. **G.** First maxilliped. **H.** Second maxilliped.

Measurements: Total length of holotype 52.5 mm.; length of carapace 15.5 mm.

Color in Life: Unknown.

Remarks: The four smallest specimens (carapace length 8.3 to 9.3 mm.) differ from the type in having much less distinct abdominal carinae and the posterior spines of the fourth and fifth somites minute, although still visible.

Of the 34 known species of *Pasiphaea*, 24 apparently have no teeth on any of the abdominal somites, seven have a tooth on the sixth somite and one, *P. orientalis* Schmitt, 1931, has teeth on the third and sixth somites but none on the fourth and fifth. *P. hoplocerca* can therefore be readily distinguished from all other described forms with the exception of the two mentioned below by the posterior spines on the fourth, fifth and sixth somites of the abdomen. Two species, *P. amplidens* Bate, 1888, and *P. longispina* Lenz, 1914, have been described from specimens in which part or all of the abdomen was missing. From the first, *P. hoplocerca* differs in the smaller gastric spine and in having the fingers of the second chelae longer rather than shorter than the palm. *P. longispina* apparently differs in having a very long horizontal gastric spine similar to that in *P. scotiae* (Stebbing, 1914) with which species it may prove to be synonymous.

Genus *Parapasiphaë* Smith, 1884.

Rostrum arising from frontal margin. Fourth pereopod shorter than fifth. Mandible with a two-jointed palp.

KEY TO THE BERMUDIAN SPECIES OF *Parapasiphaë*.

1. No spines on anterior margin of lateral portion of carapace; not more than two spines on dorsal carina of carapace 2
Antennal and branchiostegal spines present; more than two spines on dorsal carina of carapace; fingers of second chelae shorter than palm 3
2. Dorsal carina of carapace unarmed, but sulcate anteriorly; fingers of second chelae not longer than palm *P. sulcatifrons*
One or two spines on dorsal carina of carapace; fingers of second chelae distinctly longer than palm *P. macrodactyla*
3. Rostrum terminating in a short spine which does not reach beyond middle of eyestalks *P.*, sp. a.
Rostrum a long, stout spine which reaches nearly to tips of eyes *P.*, sp. b.

Parapasiphaë sulcatifrons Smith.

Text-fig. 6.

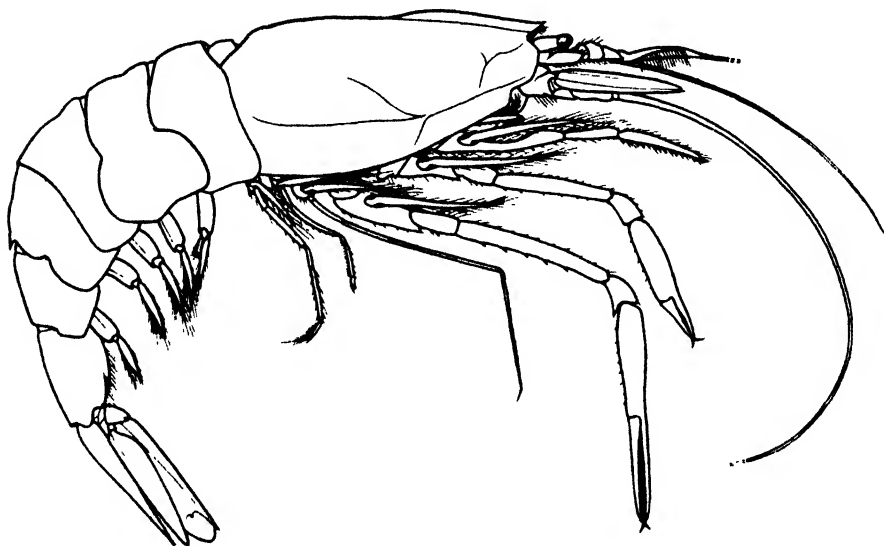
Parapasiphaë sulcatifrons Smith, 1884, p. 384, pl. 5, fig. 4, pl. 6, figs. 1-7; Stephensen, 1935, p. 34.

Diagnosis: Dorsal carina of carapace unarmed above, but the anterior fourth is broadened and provided with a well marked groove in the adult. Rostrum attains middle of eyestalk. No spine on anterior edge of lateral portion of carapace. Abdomen with a small median spine at end of fourth somite. Fingers of second chelae not longer than palm.

Measurements: The smallest recognizable male specimen, in which the appendix masculina of the second pleopods is no more than a bud, has a carapace length of 16.0 mm. The largest male has a carapace length of 22.5

mm. and the appendix masculina is about two-thirds as long as the other appendix. The ovigerous females range in carapace length from 22 to 26 mm., but only one specimen has a carapace length of less than 23 mm., whereas the females without eggs have a carapace length of 16 to 23 mm. and only one is more than 22 mm. Most of the young are little more than post-larvae, having a carapace length of only five or six mm.

Color in Life: General color scarlet, with the carapace and chelae brighter than the rest. Eyes light amber to bronze. Antennae salmon-orange and the other appendages like the body. Eggs scarlet with the developing embryo salmon-orange.



Text-figure 6.

Parapasiphae sulcatifrons. Male taken in September, 1929, from 700 fathoms. $\times 1.66$.

General Remarks: The collection contains 497 specimens of this species but only 36 are adult; 10 males and 26 females of which 14 are ovigerous. Whether this is merely indicative of the normal mortality of the young, whether proportionately larger numbers of adults might be expected in greater depths or whether some other factor is involved cannot be ascertained from the present material. *P. sulcatifrons* is one of the few bathypelagic prawns in which the stomach is occasionally everted upon being brought to the surface. Three specimens of this species were found in the stomachs of fish; one from the stomach of *Photostomias guernei* and two from *Gonostoma elongatum*.

Seasonal Distribution: Obviously the number of adults is too small to supply any information on the seasonal abundance of this form. It may be worthy of mention that ovigerous females were taken in April, June, July, August and September and attention is called to the fact that all but one of the female specimens having a carapace length of more than 22 mm. were carrying eggs. The number of immature and young, likewise, is not sufficient to warrant any definite conclusions. However, a comparison of the number of young taken in 1929 and 1930 with the towing hours at each depth indicates that the smallest number of specimens is found from April to June,

with an increase in July and August and a very slight falling off again in September.

Vertical Distribution: Of the 36 adult specimens two were taken in 600 fathoms, four in 700, eight in 800, twelve in 900 and ten in 1,000. Compared with the towing hours at each depth and realizing that open nets were employed, the center of abundance appears to be between 800 and 900 fathoms. The immature and young were found between 500 and 1,000 fathoms with two specimens being taken in 400 fathoms. Although there may be some seasonal shift in the vertical range of this population, the center of abundance seems to be between 600 and 800 fathoms, or somewhat nearer the surface than is the case for the adults.

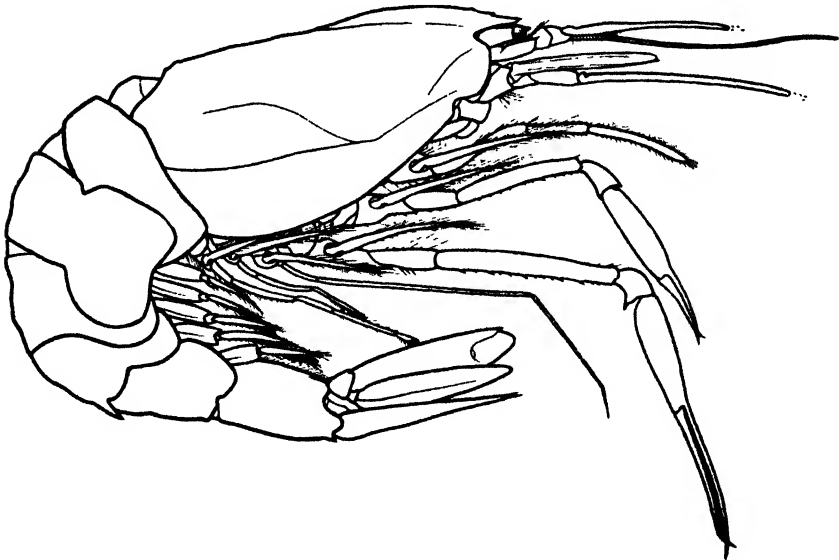
Geographical Distribution: The known distribution of the species includes the following areas; off the east coast of the United States from 35° to 41° north latitude, Davis Straits, between Greenland and Iceland, south of Iceland, southwest of Ireland, the Bay of Cadiz and, finally, off Cape Point, Cape Colony, South Africa, according to Stebbing, 1914a. This distribution would suggest that *P. sulcatifrons* is not a true Sargasso Sea form, but it is dangerous to form such conclusions until more is known of the caridean fauna of the Sargasso area.

***Parapasiphaë macrodactyla* Chace.**

Text-fig. 7.

Parapasiphaë macrodactyla Chace, 1939. p. 33.

Diagnosis: Dorsal carina of carapace armed with one or two teeth above the orbit. Rostrum reaches as far as the cornea. No spine on anterior edge of lateral portion of carapace. Abdomen with a median spine at end of fourth somite. Fingers of second chelae distinctly longer than palm.



Text-figure 7.

Parapasiphaë macrodactyla. Holotype female from off the coast of Cuba. $\times 1.88$.

Measurements: The type female from off Cuba has a carapace length of 24.8 mm. The male in the present collection has a carapace length of 19.0 mm. and the female, 21.3 mm. Similar measurements in the young range from 4.8 to 11.0 mm. In the male the appendix masculina is less than half as long as the other appendix.

Color in Life: Unknown.

General Remarks: There are 30 specimens of this species in the collection, one male, one female and 28 young. *P. macrodactyla* is easily distinguished from the preceding species, even in the smallest specimens, by the presence of one or two spines at the base of the rostrum and, particularly, by the much longer fingers of the second chelae.

Seasonal Distribution: In 1929, fifteen specimens were captured, of which nine were taken in September and the remaining six in May, June, July and August. Of the four specimens taken in 1930, three were found in September and the other in June. In 1931, eleven specimens were captured but were separated in such a way that monthly totals could not be obtained. The adult male was taken in June, 1930, and the female in September, 1929.

Vertical Distribution: Both adult specimens were found in 1,000 fathoms. Of the young, three were taken in 600 fathoms, ten in 700, four in 800, five in 900 and six in 1,000.

Geographical Distribution: Aside from the present specimens, *P. macrodactyla* is known only from the type taken off Bahia de Guantanamo, Cuba.

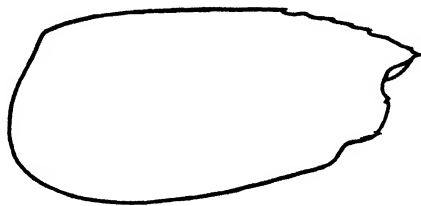
***Parapasiphaë*, sp. a.**

Text-fig. 8.

Diagnosis: Dorsal carina of carapace armed with about six small, unequal spines in its anterior half. Rostrum short, terminating in a small spine which falls far short of the tips of the eyes. Antennal and branchiostegal spines present. Abdomen carinate on third and fourth somites, the latter armed with a large, sharply carinate spine overhanging the fifth somite. Fingers of second chelae distinctly shorter than palm.

Text-figure 8.

Parapasiphaë, sp. a.
A. Lateral view of carapace. B. Chela of second pereopod.



A



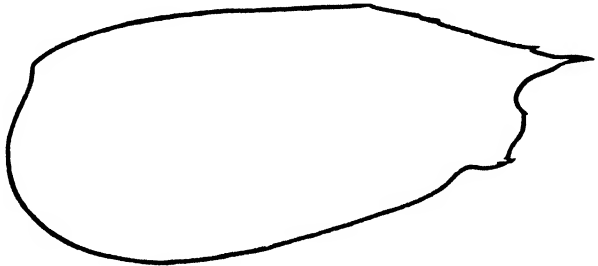
B

Remarks: This form is represented by a single young specimen having a carapace length of about 8 mm., taken in Net 819, 844, 862 or 867, August 29 to September 10, 1930, from 800 fathoms. It is apparently related to *P. serrata* Rathbun, 1902, (p. 904) and 1904 (p. 25, fig. 7), from off the coast of southern California, as indicated by the form of the rostrum, the tooth on the fourth abdominal somite and the proportionate lengths of the palm and fingers of the second chelae.

***Parapasiphaë*, sp. b.**

Text-fig. 9.

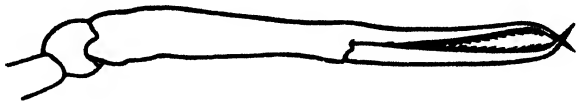
Diagnosis: Carapace denticulate on anterior half of dorsal carina and drawn out to a slender, pointed rostrum which reaches nearly to the tips of the eyes. Antennal and branchiostegal spines present. Fourth abdominal somite armed with a small tooth or spine. Fingers of second chelae somewhat shorter than palm.



A

Text-figure 9.

Parapasiphaë, sp. b. **A.** Carapace of specimen from net 1502. $\times 11$. **B.** Chela of second pereopod of specimen from net 657.



B

Remarks: Two specimens, one having a carapace length of about 6.5 mm. from Net 657, June 2, 1930, 700 fathoms, the other with a carapace length of about 5.0 mm. from Net 1502, July 25, 1934, 500 fathoms, are assigned to this indeterminable species. The larger specimen is moulting but seven distinct spines, exclusive of the long, slender rostrum, can be seen on the anterior half of the dorsal margin of the carapace. This specimen also has a distinct spine on the fourth abdominal somite. The smaller figured specimen has a similar rostrum but the spines behind it are much less distinct and the spine on the fourth abdominal somite is scarcely visible. The form of the rostrum and the denticulate carina of the carapace recalls similar structures in *P. gilesii* Wood-Mason, 1893 (p. 166), and Ill. *Investigator* (pl. 3, fig. 8) from the Indian Ocean.

Genus **Leptochela** Stimpson, 1860.

Rostrum arising from frontal margin. Last three pereopods similar, diminishing in length from third to fifth. Mandible with a palp which consists of a single joint. Adults usually less than an inch in length.

There is but one species of the genus known from the Bermuda area.

Leptochela bermudensis Gurney.

Text-fig. 10.

Leptochela bermudensis Gurney, 1939, pp. 426-433, figs. 1-10.

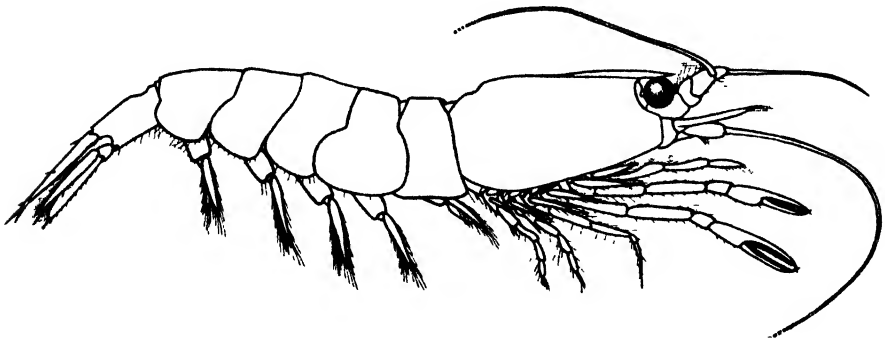
Diagnosis: Orbital margin smooth, not denticulate. Abdomen not carinate on fourth or fifth somites; telson with one pair of dorsal and one pair of lateral spines.

Measurements: The two males in the collection have a carapace length of 3.2 and 4.5 mm. The females have corresponding measurements of 2.9 to 3.2 mm., both ovigerous females having the carapace 3.2 mm. long. In the young the carapace is from 1.3 to 1.8 mm. long.

Color in Life: Integument transparent, showing the pinkish or brownish heart and other whitish internal organs. Bases of all legs and middle of second segments of pleopods bright spectrum red; in one ovigerous female these markings were pure scarlet instead of spectrum red. All appendages otherwise transparent with a faint violet tinge on the distal segments. In one lot, faint scarlet markings were noticed on the maxillipeds. Eyes deep, dull violet-blue. Eggs orange-pink.

A number of these prawns were kept alive in a refrigerator for about eighteen hours. At about the tenth hour, lateral spectrum red spots appeared on the abdomen, the violet tinge became more pronounced and in the larger specimens the internal organs appeared greenish-yellow.

General Remarks: Since there are only sixteen specimens in the collection, two males, six females, of which two are ovigerous, and eight young, it is probable that the species is found only sporadically in the Bermuda area. There also is a good indication that swarming occurs in this species, for Gurney obtained no less than 45 adult individuals from a single net. As in other species of the genus, ovigerous females have three dorsal carinae on the carapace, whereas males and females without eggs have only the median



Text-figure 10.

Leptochela bermudensis. Male from net 989. $\times 6$.

carina developed for the entire length. Of the specimens kept alive in the refrigerator, a few of the smaller ones became very lively after their periodic removal from the ice, but the larger specimens were at all times sluggish and feeble.

Luminescence: The following notes were made by Miss Crane on specimens taken in Net 1028; June 20, 1931; surface at night.

"These abundant small shrimps seemed to be the source of most of the luminescence in this net (save for the minute sparks furnished by very small copepods). They emitted, both when isolated and when in the company of their kind, short, tiny flashes of bright white light. The part of the body from which these flashes came could not be determined. Dissection was not particularly helpful, as no structures were found which resembled typical light-organs of any kind I have yet observed: the best possibility seems to be that the pigment spots, seemingly superficial, at the bases of the pleopods, are in reality photophores.

"Although a couple of specimens were kept alive until the following evening by frequently changing the water and by alternately placing them in and removing them from the refrigerator, no luminescence whatever was produced even by tapping the glass and directly prodding them. They were dead the following morning."

Seasonal Distribution: The type specimens, of which twelve were ovigerous, were taken on June 14, 1938. In the present collection one male and three females were captured on September 25, 1930; one female on September 26, 1930; one male, one ovigerous female and five young on June 3, 1931; three young on June 20, 1931; and one ovigerous female on November 2, 1931.

Vertical Distribution: There is evidence of a marked diurnal migration in this species. Between one and two P.M., specimens were found at 700 fathoms; between nine-thirty A.M. and one P.M. they were taken in 400 fathoms; and three lots were taken in surface nets between seven-thirty and eight P.M., between eight-thirty and nine P.M. and between nine-thirty and ten P.M. Apparently *L. bermudensis* is normally found at or near the surface at night and sinks to considerable depths during the hours of sunlight.

Geographical Distribution: According to our present knowledge, *L. bermudensis* is known only from the Bermuda region.

Family Oplophoridae.

Rostrum always present but extremely variable in form. First two pairs of pereopods chelate, usually shorter than the last three pairs and with the carpus undivided. Last three pairs not abnormally long. Exopods present on the maxillipeds and on all of the pereopods, but there is no lash on the exopod of the first maxilliped. Terminal joint of second maxilliped applied as a strip to the end of the preceding joint. Mandibles imperfectly cleft and provided with a palp.

KEY TO THE GENERA OF OPLOPHORIDAE.

1. Exopods of at least the third maxillipeds and first pair of pereopods foliaceous and often rigid; outer margin of antennal scale usually armed with a series of spines; telson not truncate at tip, but ending in a sharp point; eyes large and well pigmented *Oplophorus*
- None of the exopods of the pereopods foliaceous or rigid 2
2. Last four abdominal somites, at least, dorsally carinate 3
- Sixth abdominal somite not dorsally carinate 4

3. Usually no straight ridge or carina running entire length of lateral surface of carapace along median lateral line; hind margin of hepatic furrow not usually cut off abruptly by an oblique ridge or carina. Incisor process of mandible toothed for entire length of the cutting edge
Acanthephyra
Carapace provided with at least one straight carina traversing the lateral surface from orbit to hind margin of carapace; hind margin of hepatic furrow abruptly cut off from branchial region by an oblique carina. Anterior half of cutting edge of incisor process of mandible unarmed
Notostomus
4. Ischial and meral joints of pereiopods abnormally broad and flat *Ephyrina*
Pereiopods normal 5
5. Eyes very small and poorly pigmented; anterior margin of first abdominal somite entire, not toothed; telson terminating in a truncate, spinose tip
Hymenodora
Eyes very large and well pigmented; anterior margin of first abdominal somite armed with a distinct lobe or tooth overlapping hind margin of carapace; telson terminating in a sharp-pointed end-piece laterally armed with spines
Systellaspis

Genus ***Acanthephyra*** A. Milne Edwards, 1881a.

Carapace usually without a straight ridge or carina running along the median lateral line from orbit to hind margin, and without an oblique ridge or carina delimiting the hind margin of the hepatic furrow. Abdomen carinate on the last four somites, at least. Telson more or less truncate at the tip, not terminating in a sharply pointed end-piece laterally armed with spines. Pereiopods not abnormally broad and flattened. Exopods of third maxillipeds and pereiopods neither foliaceous nor rigid. Eyes well pigmented even when small. Outer margin of antennal scale not armed with a series of spines. Incisor process of mandible toothed for the entire length of its cutting edge.

KEY TO THE BERMUDIAN BATHYPELAGIC SPECIES OF *Acanthephyra*.

1. Second somite of abdomen dorsally carinate; integument firm 2
Second somite of abdomen not dorsally carinate; integument membranous 7
2. Carapace not dorsally carinate on posterior third 3
Carapace dorsally carinate throughout its length 6
3. Branchiostegal spine supported by a very short carina 4
Branchiostegal spine supported by a long carina which extends back to posterior half of branchial region 5
4. No posterior spine on fourth abdominal somite; telson armed with about four pairs of lateral spines *A. purpurea*
A posterior spine on fourth abdominal somite; telson armed with eight to eleven pairs of lateral spines *A. haeckelii*
5. Rostrum triangular and drawn out to a sharp point; telson armed with six to fifteen pairs of lateral spines *A. curtirostris*
Rostrum very convex dorsally so that it appears somewhat semicircular in outline; telson armed with about three pairs of lateral spines *A. stylorostrata*

6. First abdominal somite dorsally carinate; telson obscurely sulcate dorsally *A. acutifrons*
First abdominal somite not dorsally carinate; telson obscurely ridged dorsally *A. eximia*
7. Third abdominal somite armed with a large, fleshy spine which usually overreaches fourth somite *A. brevirostris*
Spine of third abdominal somite, if present, not abnormally large 8
8. A spine on third abdominal somite *A. gracilipes*
No spine on third abdominal somite *A.*, sp. ?

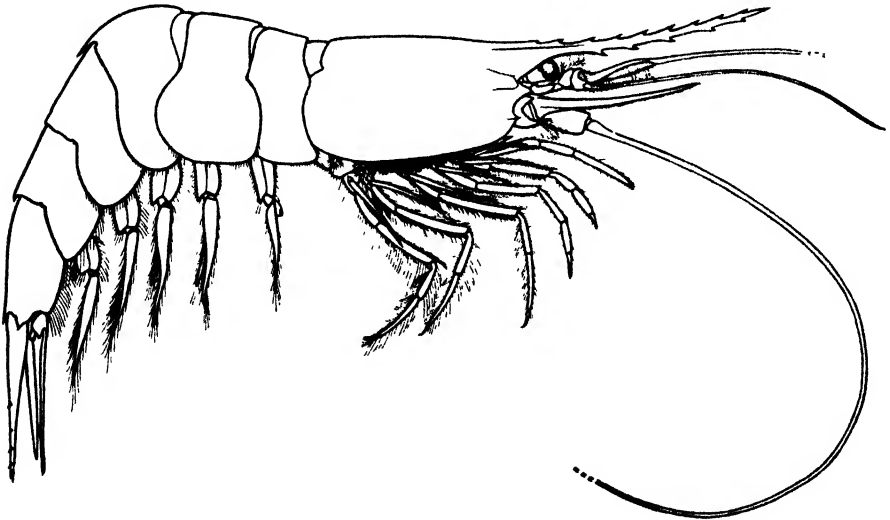
***Acanthephyra purpurea* A. Milne Edwards.**

Text-figs. 11-17.

Acanthephyra purpurea A. Milne Edwards, 1881, p. 933; Murray & Hjort, 1912, pl. 3, fig. 2, (col. fig.); Stephensen, 1923, p. 44; Kemp, 1939, p. 576.

Diagnosis: Integument firm. Rostrum long and slender. Carapace not dorsally carinate posteriorly. Branchiostegal spine supported by a short carina. Abdomen carinate on all but the first somite and with a median posterior spine on the third, fifth and sixth somites, but without any on the fourth; telson dorsally sulcate on proximal half and armed usually with four pairs of lateral spines.

Measurements: The smallest recognizable males in which the appendix masculina is little more than a bud have a carapace length of 7.5 mm. The largest male in the collection has a carapace length of 18.8 mm. and all of the larger specimens, in which the carapace is more than 17 mm. long, are males. The smallest ovigerous female examined has the carapace measuring 9.5 mm. Incidentally, the eyes of the embryos were easily seen in the eggs of this specimen, indicating that they were nearly ready to hatch. The youngest specimens have a carapace length of about 3.0 mm.



Text-figure 11.

Acanthephyra purpurea. Male taken in August, 1931, from 600 fathoms. \times 1.58.

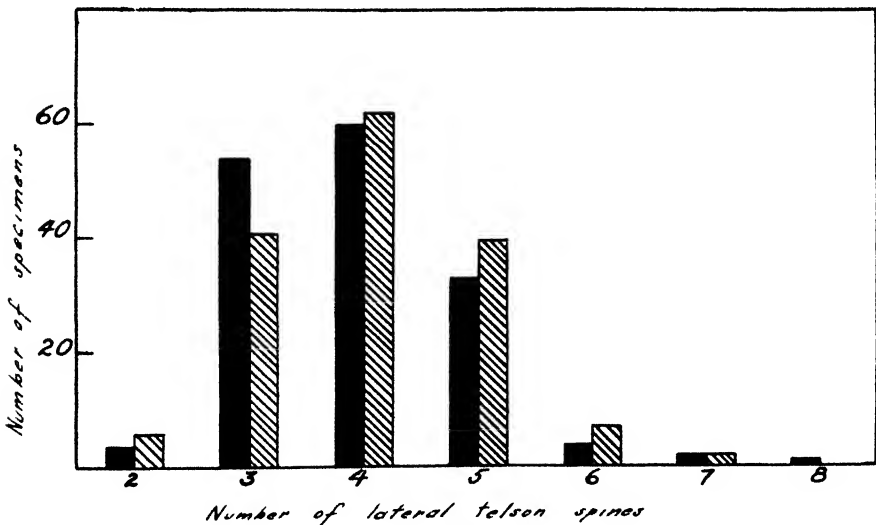
Color in Life: Body and appendages brilliant scarlet-red with setae of flame-scarlet. Eye black. Eggs scarlet-red, with the abdominal portion of the developing embryo peach-red.

General Remarks: The collection contains 4,572 specimens of this species; 909 males, 796 females, of which 278 are ovigerous, and 2,867 young. Of the ovigerous specimens, 79 are carrying eggs in which the eyes are visible.

A. purpurea is distinguished from the following species by the absence of a tooth or spine on the fourth abdominal somite, by having fewer lateral spines on the telson and by its somewhat smaller size. There is but one specimen in the collection, a female with a carapace length of 9.0 mm., which has the combination of four pairs of telson spines and a tooth on the fourth abdominal somite. Of the 4,572 specimens, only 158 do not have four spines on either side of the telson. This does not take into consideration about 3.7 per cent of the remaining 4,414 specimens in which the telson is damaged so that the determination of the number of telson spines is impossible. If allowance is made for this, however, probably all but three or four per cent of the specimens have the normal armature of four spines on either side of the telson. Text-fig. 12 shows graphically the numerical distribution of the spines in those specimens which do not have four pairs of lateral telson spines. Of these 158 specimens, 122 have the normal number of four spines on either the right or the left side of the telson. If the number of specimens is doubled to include the spines on either side, it is found that in only 26 out of 316 cases are there more or less than three to five spines, and in practically all of these few instances the telson is so malformed that it might be classed as a freak or as the result of injury.

The following notes on the eggs and embryos of this species were made by Miss Crane from a specimen taken in Net 1107; July 27, 1931; 400 fathoms.

"Silky threads bind the eggs to one another, the substance seemingly



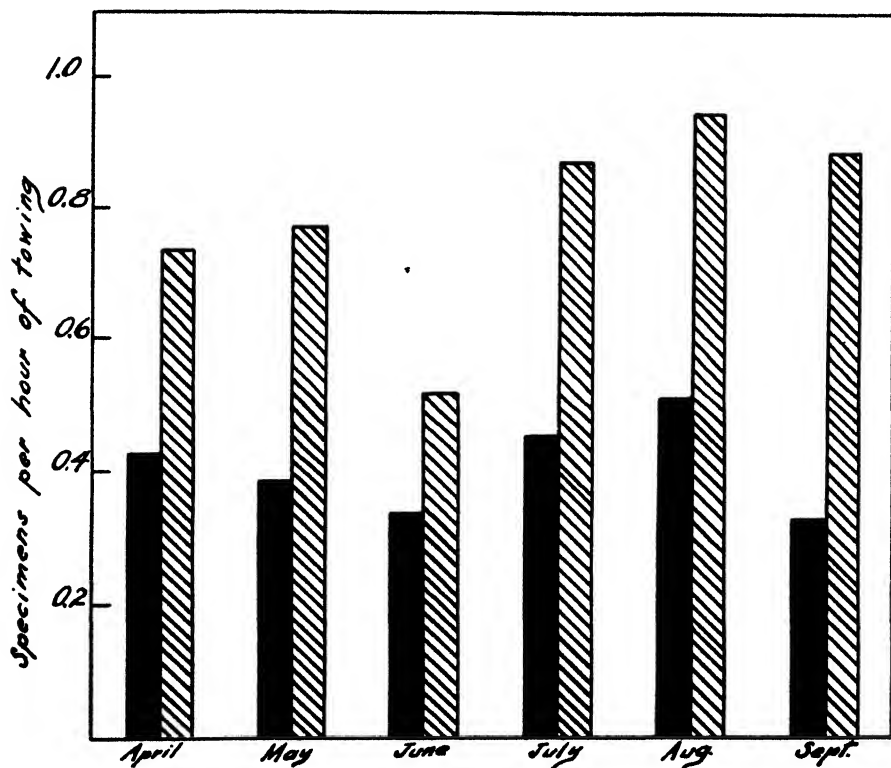
Text-figure 12.

Distribution of lateral telson spines in individuals of *Acanthephyra purpurea* which do not have four spines on either side of the telson. Solid bars represent spines on the left side of the telson; hatched bars those on the right.

continuous with the egg membrane itself. There are usually half a dozen points of attachment on each egg—one at each end and four in the vicinity of the equator. These threads are very fine, though tough and elastic, and in at least several I can quite clearly see that they are tubular in structure—as if each egg were enclosed in the common atrium into which the six tubes open.

“The well-formed, salmon-orange embryos are nearly ready to hatch, the tip of the abdomen in some cases already projecting from the ruptured, transparent egg membrane. The scarlet-red yolk sac remains only along the dorsal side of the head and thorax of each embryo, which is curled up in the longitudinal plane of the egg, the abdomen flexed beneath the thorax. The uropods and telson, perfectly formed except for the four or five pairs of spines and the feathery setae of the adult, fit exactly between the two pairs of antennae, which are already the longest of the appendages. I am reasonably certain that the enormous structure almost covering the side of the head is a compound eye, comparable to that of a Hyperiid amphipod, but further observation is required. The anlage of the rostrum is visible as a small, blunt projection. The thoracic appendages are outlined, but fixed to one another, and there are, of course, no pleopods.”

In three instances, *A. purpurea* was found in the stomach of the fish, *Gonostoma elongatum*.

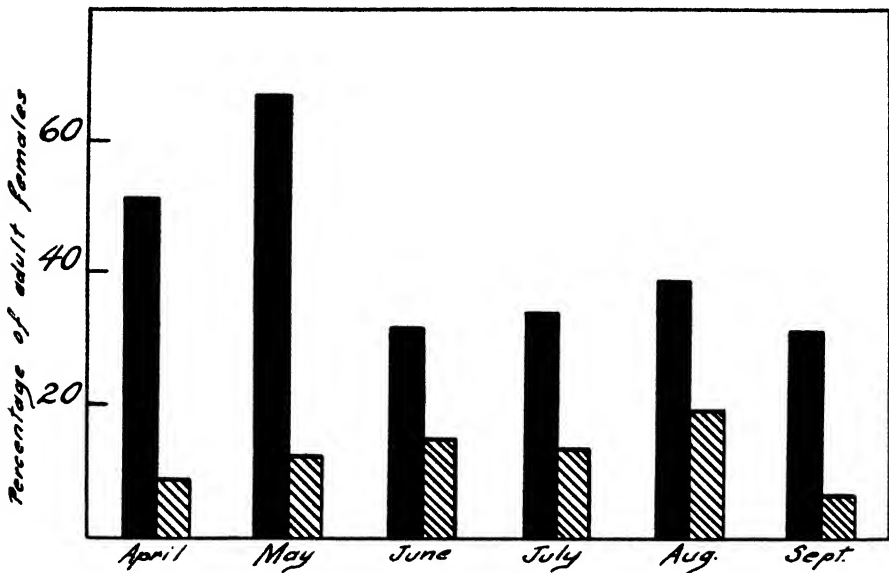


Text-figure 13.

Seasonal distribution of adults (solid bars) and young (hatched bars) of *Acantheephyra purpurea* computed from specimens taken in 1929 and 1930 between 500 and 1,000 fathoms.

For remarks on the food of this species, see the general discussion at the end of this paper.

Seasonal Distribution: Text-fig. 13 shows the fluctuation in the population of *A. purpurea* from April to September for the years 1929 and 1930. Although the population, particularly in regard to the proportion of young or immature specimens, is reasonably uniform throughout this period of the year, it will be noted that there is apparently a perceptible increase in the total population in July, August and September. It will also be noticed that there is a much greater proportion of young in September than in June. Although a slightly larger proportion of the September tows were made in shallow water where young are somewhat more abundant, this difference is hardly great enough to produce such a change in the total population. It must be kept in mind that no attempt was made to segregate various sizes of young and the presence of more than one age class might very well serve to confuse the general aspect of the results. However, there is certainly an indication of an increase in the numbers of young individuals early in the fall.



Text-figure 14.

Seasonal distribution of ovigerous females of *Acantheephyra purpurea* computed from specimens taken in 1929 and 1930 between 500 and 1,000 fathoms. Solid bars represent the percentage of all females which were ovigerous; hatched bars the percentage of all females which carried eggs in which the eyes were visible.

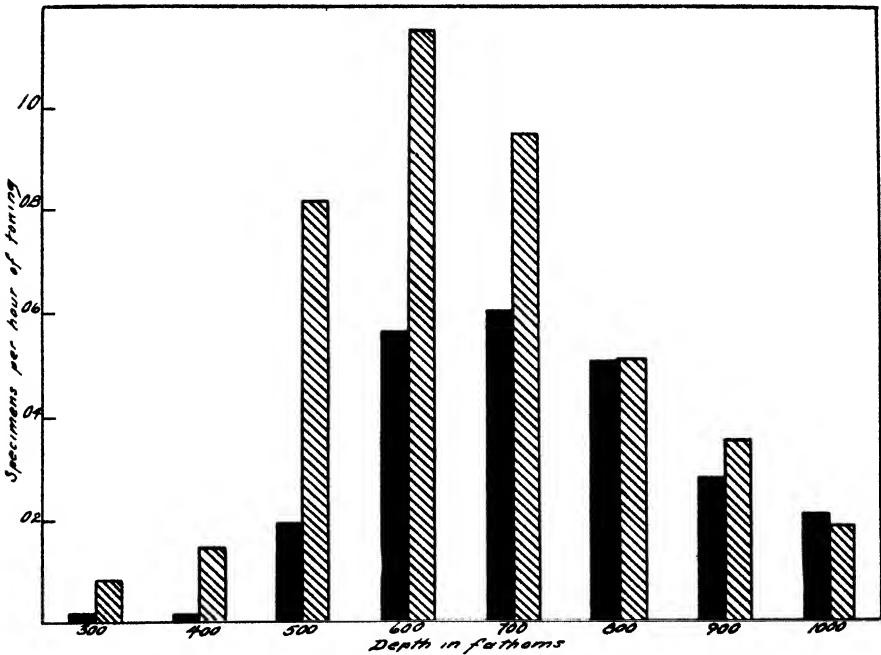
The distribution of ovigerous females over the same six months period, as shown in Text-fig. 14, indicates little more than that there is no sharply defined "breeding period" during this part of the year. Whether the eggs are carried throughout the year in this area can be ascertained only by additional towing in the winter months. The suggestion has been advanced that the eggs are carried by the female for a considerable length of time but hatch only during a short period when conditions are most favorable, but if it is assumed that eggs in which the eyes of the larvae are visible are nearly ready to hatch the present material would seem to refute this hypothesis.

Vertical Distribution: The vertical distribution of the total catch of *A. purpurea* from 1929 through 1935 is given in the following table:

Fathoms	Males	Females	Young
300.....	2.....	2.....	19
400.....	2.....	1 (ovig.).....	31
500.....	57.....	80 (31 ovig.).....	584
600.....	161.....	220 (79 ovig.).....	782
700.....	227.....	193 (80 ovig.).....	662
800.....	203.....	150 (51 ovig.).....	356
900.....	138.....	70 (16 ovig.).....	260
1,000.....	115.....	78 (20 ovig.).....	171
1,100.....	4.....	1.....	2
1,200.....	.....	1.....	.....

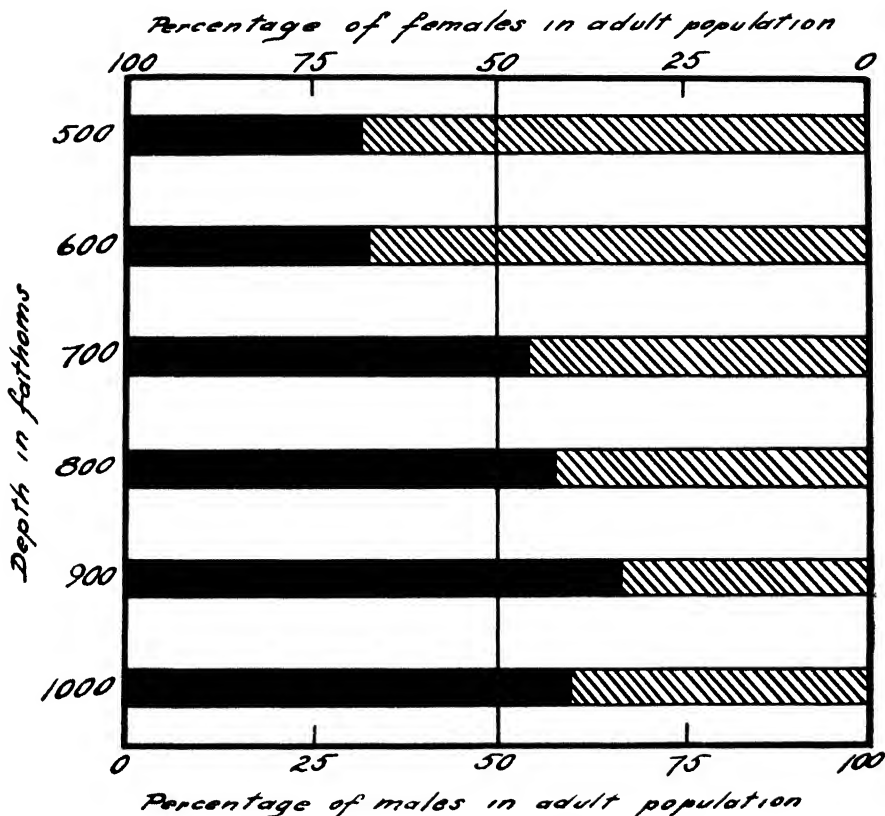
Text-fig. 15 shows the distribution of all adult and young specimens captured between 300 and 1,000 fathoms. All of these specimens were taken in the daytime; in fact, I have seen no specimens from nets 224 to 229 which were towed at night between 500 and 1,000 fathoms. This may or may not indicate that the center of distribution of the species is above 500 fathoms at night (see Welsh, Chace & Nunnemacher, 1937, p. 190). It is obvious that in the daytime most adults are to be found between 600 and 800 fathoms and, inasmuch as open nets were employed, it is not unlikely that there are fewer individuals at 900 and 1,000 fathoms than indicated here. The center of abundance of the young population, on the other hand, is slightly nearer the surface, between 500 and 700 fathoms, and the greatest number of young in proportion to the number of adults is found at 500 fathoms.

This collection has disclosed the interesting fact that the male portion



Text-figure 15.

Vertical distribution of adults (solid bars) and young (hatched bars) of *Acantheephyra purpurea*.

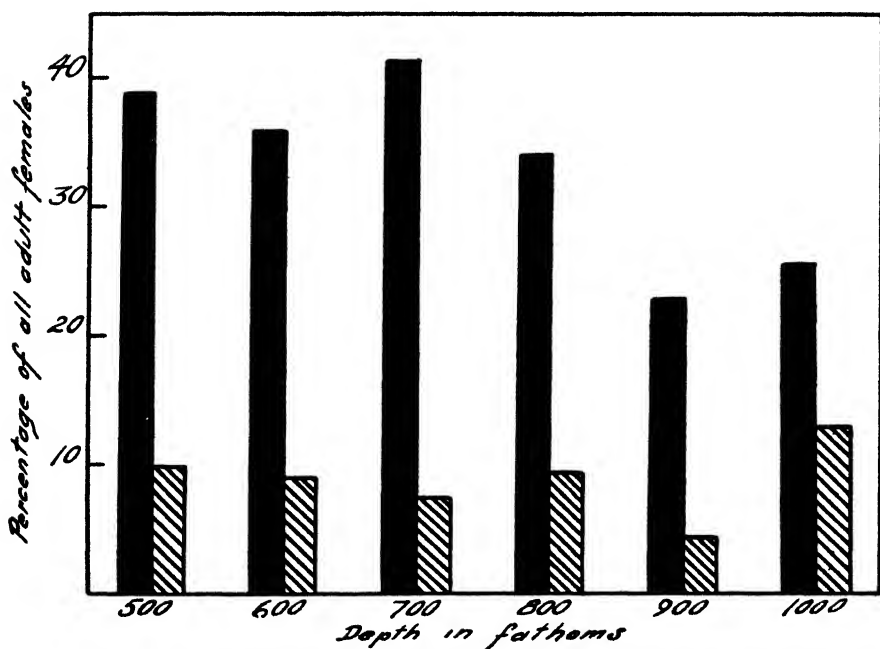


Text-figure 16.

Relative abundance of males and females of *Acantheephyra purpurea* from 500 to 1,000 fathoms. Solid bars represent the male fraction of the adult population; hatched bars the female.

of the adult population is found in somewhat deeper water than the female portion, as shown in Text-fig. 16. If these findings accurately represent the actual conditions, one would expect to find equal numbers of males and females at about 675 fathoms, whereas above that level the females are in the majority and below it, the males. Whether the female population increases slightly again in proportion at 1,000 fathoms as shown by these data is problematical since it must be kept in mind that catches from the deeper tows must have been somewhat contaminated with specimens from lesser depths through the use of open nets. It might be supposed that this curious distribution of the two sexes in *A. purpurea* could be accounted for by the possibility that ovigerous females came up into lesser depths to hatch their eggs, but this is hardly borne out by the present material as shown in Text-fig. 17, which shows the percentage of all females which are ovigerous at each depth. Although there is a slightly larger proportion of ovigerous females from 500 to 800 fathoms, the largest fraction is found at 700 fathoms where more than half of the population is made up of males. These data also tend to refute the theory that the eggs are hatched near the surface, for the largest proportion of specimens carrying eyed eggs was taken in 1,000 fathoms.

Geographical Distribution: Inasmuch as many workers, including my-



Text-figure 17.

Vertical distribution of ovigerous females of *Acantheephyra purpurea*. Solid bars represent the percentage of all females which were ovigerous; hatched bars the percentage of all females which carried eggs in which the eyes were visible.

self, have previously confused several closely related species with *A. purpurea*, the distribution of this form is somewhat in doubt. However, as Kemp (1939) has shown, it is not a world-wide form as generally considered, but is probably restricted to the north Atlantic between about 20° and 53° north latitude.

***Acantheephyra haeckelii* (von Martens).**

Text-figs. 18-20.

Ephyra Haeckelii von Martens, 1868, p. 54, pl. 1, figs. 7a-b.

Acantheephyra agassizii Smith, 1884 (not 1882), p. 372 (part), pl. 8, fig. 1.

Acantheephyra sica Bate, 1888, p. 739, pl. 125, fig. 1.

Acantheephyra rectirostris Riggio, 1901, p. 20.

Acantheephyra purpurea var. *multispina* Coutière, 1905, p. 10.

Acantheephyra multispina Murray & Hjort, 1912, pl. 3, fig. 1 (col. fig.); Stephensen, 1923, p. 44.

Acantheephyra haeckelii Kemp, 1939, p. 575.

Diagnosis: Integument firm. Rostrum long and slender. Carapace not dorsally carinate posteriorly. Branchiostegal spine supported by a short carina. Abdomen carinate on all but the first somite and with a medium posterior spine on the third, fourth, fifth and sixth somites; telson dorsally

sulcate on proximal half and armed usually with eight to eleven pairs of lateral spines.

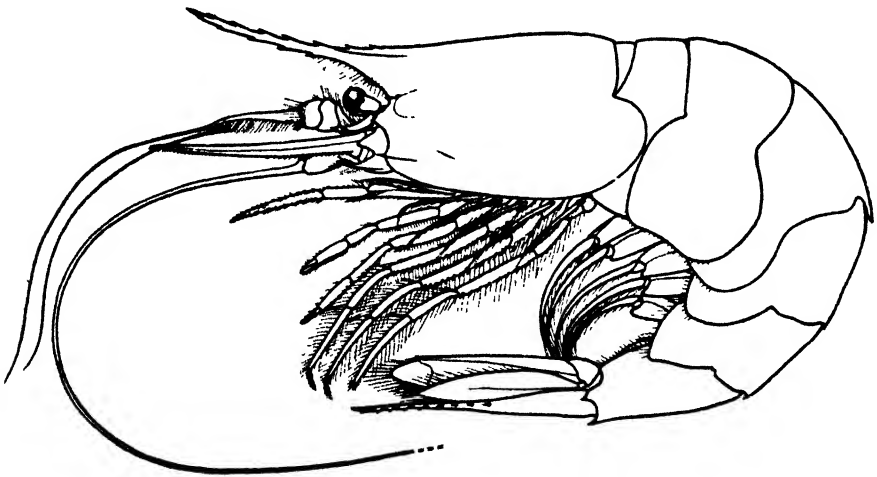
Measurements: The smallest recognizable male has a carapace length of 10.0 mm. The largest male in the collection has a carapace length of 24.0 mm., and the largest female, 24.5 mm. Of thirteen specimens in which the carapace measures 20.0 mm. or over, ten are males and three females. In the smallest specimen seen, the carapace measures 2.6 mm.

Color in Life: Body and appendages brilliant scarlet-red, with the setae somewhat lighter and with the antennae, antennal scales and proximal segments of the pleopods tinged with salmon-orange. Eyes black.

General Remarks: This species is much less common in the Bermuda area than the last. The collection contains only 217 specimens, of which 35 are males, 36 females and 146 young.

A. haeckelii can be readily distinguished from *A. purpurea* by the tooth on the fourth abdominal somite and the greater number of dorso-lateral spines on the telson. It will be seen from Text-fig. 19 that the most common number of lateral telson spines on either side is nine, followed in order by ten, eight, and eleven. Six, seven, twelve and thirteen spines occur so rarely that such a condition might well be regarded as abnormal. This species also attains a larger size than the preceding, and the rostrum is usually somewhat shorter proportionately in the Bermuda specimens. In studying the present collection, it was noticed that in the preserved specimens of *A. haeckelii* the abdomen was generally fully flexed as in the accompanying figure, whereas in those of *A. purpurea* it is usually merely bent sharply at the third somite, and the dorsal margins of the fourth and fifth somites most frequently form a straight line.

It is noteworthy that none of the females carried eggs. On the basis of the percentage of ovigerous specimens in *A. purpurea*, one would expect about twelve of the 36 females of *A. haeckelii* to be ovigerous also. The most plausible explanation would seem to be that this region is not included in the normal range of the species and that breeding does not occur due to the unfavorable conditions. There is the possibility, of course, that ovigerous females might be found during the winter months, but the apparent absence of any well defined "breeding season" in *A. purpurea* would tend to preclude



Text-figure 18.

Acanthephyra haeckelii. Male taken in September, 1929, from 900 fathoms. $\times 1.45$.



Text-figure 19.

Distribution of the lateral telson spines in *Acanthephyra haeckelii*. Solid bars represent the spines on the left side of the telson; hatched bars those on the right.

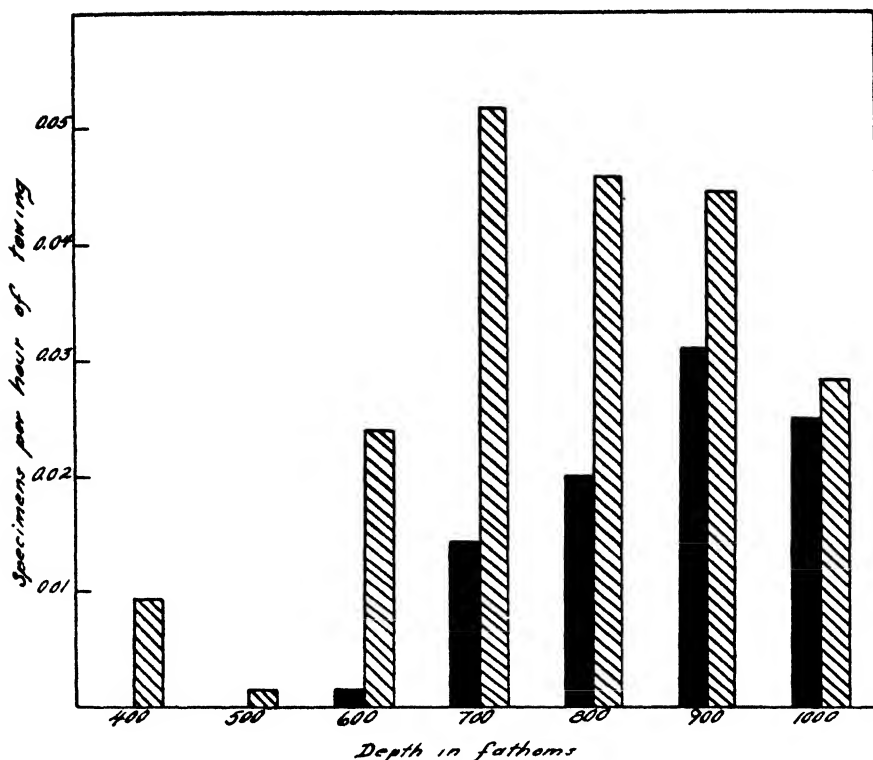
this possibility. Finally, one must not entirely disregard the chance that a greater number of females might disclose some with eggs, especially since Stephensen, 1923, reports finding only seven out of 72 females of this species carrying eggs in contrast to 17 out of 58 in the case of *A. purpurea*.

Seasonal Distribution: The number of specimens is obviously too small to give any indication of the seasonal distribution of the species. Both adults and young were taken in every month of 1929 and 1930 in which towing was done, i.e. from April to September.

Vertical Distribution: The following table shows the vertical distribution of the total catch of *A. haeckelii* from 1929 through 1935:

Fathoms	Males	Females	Young
400 .....			.2
500 .....			.1
600 .....	.1		.16
700 .....	.3	.7	.36
800 .....	.8	.6	.32
900 .....	.15	.8	.33
1,000 .....	.8	.15	.26

When correlated with the number of hours of towing at each depth, these data are shown graphically in Text-fig. 20. All of these specimens were taken in the daytime. A comparison with the vertical distribution of *A. purpurea* leaves little doubt that *A. haeckelii* is usually found at greater depths in the area in question. In *A. purpurea* the center of the adult population was found to be between 600 and 800 fathoms, whereas in *A. haeckelii* it seems to be at about 900 fathoms. The greatest number of young, although higher in the water than the adults, were not as near the surface as those of *A. purpurea*. In the latter, the young were most numerous at from



Text-figure 20.

Vertical distribution of adults (solid bars) and young (hatched bars) of *Acantheephyra haeckelii*. 500 to 700 fathoms, while in *A. haeckelii* the center of abundance seems to be between 700 and 900 fathoms.

Geographical Distribution: This species is known from the North Atlantic as far north as Davis Strait, the Mediterranean and the South Atlantic, South Pacific and Indian Oceans. In the western North Atlantic *A. haeckelii* seems to be much commoner than *A. purpurea* west of the Gulf Stream, whereas the present collection certainly indicates that the reverse is true in the Sargasso area. Our present knowledge of the distribution of the two species in the North Atlantic would lead to the assumption that *A. haeckelii* is normally a colder water form than *A. purpurea*.

***Acantheephyra curtirostris* Wood-Mason.**

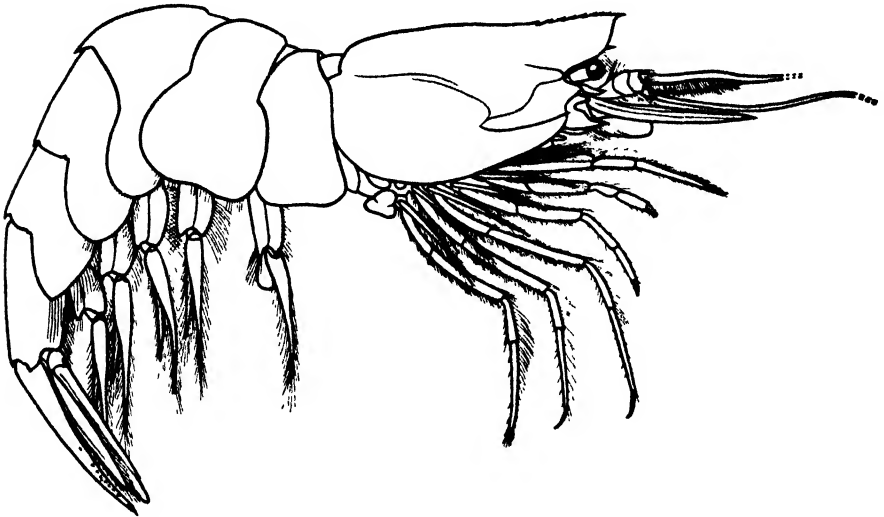
Text-fig. 21.

Acantheephyra curtirostris Wood-Mason, 1891, p. 195; Balss, 1925, p. 261, fig. 30 (mandible); Chace, 1937, p. 111.

Diagnosis: Integument firm. Rostrum not reaching beyond antennular peduncle and with a single spine on lower margin. Carapace not dorsally carinate posteriorly. Branchiostegal spine supported by a carina which extends back to posterior part of branchial region. Abdomen carinate on all but the first somite and with a median posterior spine on the third, fourth, fifth and sixth somites; telson dorsally sulcate on proximal half and armed with six to fifteen dorso-lateral spinules.

Color in Life: Crimson (Alcock, 1901). From recently preserved specimens, both from the Atlantic and the Pacific, I would infer that the general color of this species is very similar to that in *A. purpurea* and *A. haeckelii*.

Remarks: This species is represented by a single young specimen (carapace length, 4.0 mm.) from Net 1273, 1279, 1285, 1293, 1316 or 1328, September 7 to 19, 1932, from 800 fathoms. Had I not recently seen several adult specimens of this species from the West Indian region, I should have been very hesitant about the determination of this young specimen, but there is little doubt that it belongs to this species.



Text-figure 21.

Acantheephyra curtirostris. Male from Tongue of the Ocean, Bahamas. $\times 1.44$.

Geographical Distribution: *A. curtirostris* ranges from the east coast of Africa through the Indian Ocean, Malay, Philippine and Japanese regions to the Hawaiian Islands and the west coast of America from San Diego to Peru. In the Atlantic it has been known only from a specimen in the U. S. National Museum taken off British Guiana. Recently I have seen several specimens taken by the *Pawnee* in the Bahaman region and by the *Atlantis* off the north and south coasts of Cuba. Although apparently less common in the Atlantic than off the Pacific coast of America, the limits of range in both areas appear to be similar.

***Acantheephyra stylorostrata* (Bate).**

Text-fig. 22.

? *Bentheocaris exuens* Bate, 1888, p. 724, pl. 123, figs. 3-30.

Bentheocaris stylorostratis Bate, 1888, p. 726, pl. 123, figs. 4-40.

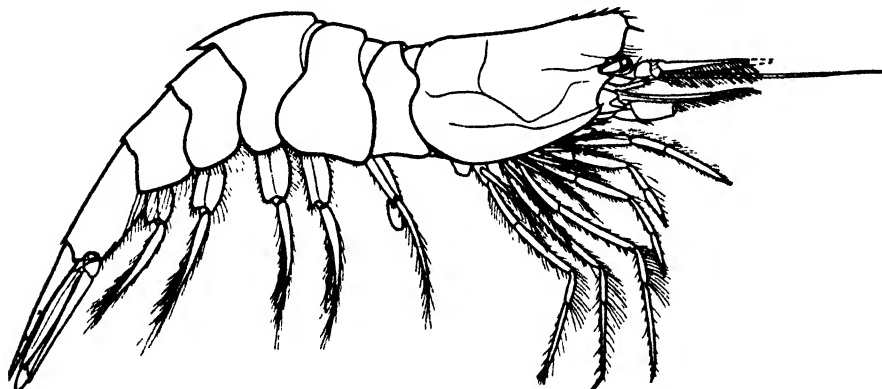
Acantheephyra stylorostratis Calman, 1925, p. 14; Chace, 1936, p. 30.

Diagnosis: Integument rather firm but by no means hard. Rostrum short and high and somewhat semicircular in outline. Carapace not dorsally carinate posteriorly. Branchiostegal spine supported by a long carina which passes back onto the posterior part of the branchial region. Abdomen carinate on all but the first somite and with a median posterior spine on the

third, fourth, fifth and sixth somites; telson dorsally sulcate and armed normally with three pairs of lateral spines.

Measurements: The smallest recognizable males have a carapace length of 8.5 mm. The largest male has a carapace length of 16.2 mm., and the largest female, 13.5 mm. In the smallest of the five ovigerous females taken, the carapace is 10.0 mm. long. The carapace of the smallest young individual measures 2.9 mm. In this and the preceding species the carapace length is shorter in relation to the abdomen than in most other species of the genus, so the total body length, exclusive of the rostrum, will be somewhat greater in these two forms than in specimens of other species of similar carapace measurements.

Color in Life: Body and appendages brilliant scarlet, with salmon-orange setae on antennae, pereopods and pleopods. Eyes golden-bronze, speckled with black. Eggs scarlet.



Text-figure 22.

Acantheephyra stylostrata. Male taken in June, 1930, from 900 fathoms. $\times 1.74$.

General Remarks: This species is represented by 91 specimens; 17 males, 15 females, of which 5 are ovigerous, and 54 young.

The form of the rostrum distinguishes this species at a glance. It is very probable that Bate's *Bentheocaris exuens* is the same species but, inasmuch as Calman states that the type is in such condition that comparison is almost impossible and as Bate's figure is inadequate, it seems best to retain the much more suitable name, *stylostrata*, for this form.

Practically all of the specimens in the collection have three pairs of dorso-lateral spines on the telson; I have seen but two which vary from this pattern and they have four on the left side and three on the right.

Vertical Distribution: The following table shows the depths at which this species were found:

Fathoms	Males	Females	Young
600			2
700		1 (ovig.)	6
800	2	5 (2 ovig.)	11
900	5	4 (1 ovig.)	21
1,000	10	5 (1 ovig.)	13
1,100			
1,200			1

Seasonal Distribution: There is no obvious seasonal or yearly variation in the numbers of specimens found in the Bermuda area. Of the five oviger-

ous females, two were taken in July, 1930, one either in June, July or August, 1931, one in August, 1931, and one in October, 1931. In one of the specimens taken in July, 1930, the eyes of the larvae can be seen through the egg membranes.

Obviously, *A. stylostrata* is a deep water species usually found from 800 to 1,000 fathoms. Although the number of adults taken was small, it will be noticed that, as in *A. purpurea*, the males seem to be found at somewhat deeper levels than the females. The single female which carried eyed eggs was found at 1,000 fathoms. Even the young of this species seem to be found in considerable depths, since the greatest number came from 900 fathoms.

Geographical Distribution: *A. stylostrata* has been recorded previously in the eastern North Atlantic in the region of Madeira, the Canaries and the Cape Verde Islands as far west as 45° west longitude. A few specimens have been seen from the region of the Gulf Stream east of New Jersey, and Calman records specimens from off Natal, South Africa. *Bentheocaris exuens*, which is probably the same species, came from the South Pacific south of the Tuamotu Archipelago.

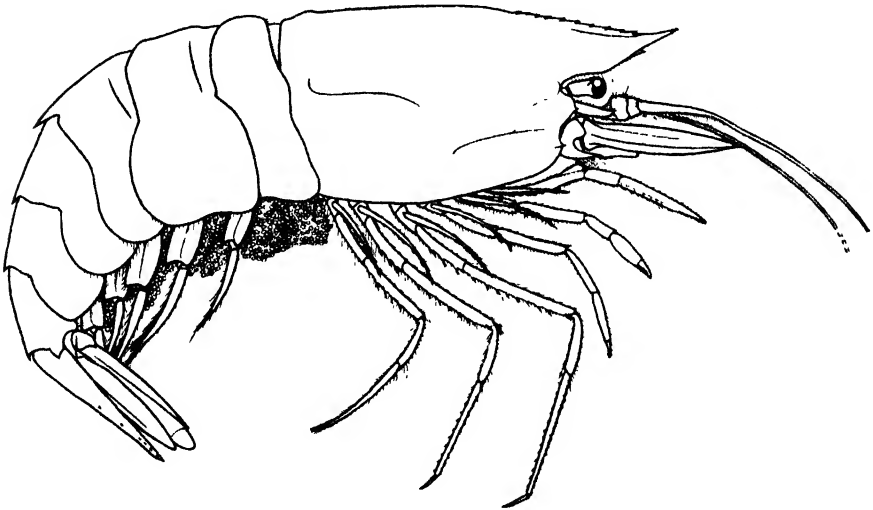
***AcanthePHYRA acutifrons* Bate.**

Text-fig. 23.

AcanthePHYRA acutifrons Bate, 1888, p. 749 (part), pl. 126, fig. 3; Kemp, 1906, p. 20; Balss, 1925, p. 261.

Diagnosis: Integument firm but not hard. Rostrum rather short and deep with a single ventral tooth. Carapace dorsally carinate for its entire length. Branchiostegal spine supported by a short, rounded ridge. Abdomen carinate on every somite and with a median posterior spine on the third, fourth, fifth and sixth somites; telson dorsally sulcate and armed with five or six pairs of lateral spinules.

Color in Life: Unknown.



Text-figure 23.

AcanthePHYRA acutifrons. Ovigerous female from Tongue of the Ocean, Bahamas. $\times 0.80$.

Remarks: Two young specimens (carapace lengths, 5.1 and 7.1 mm.) from Net 813, 823, 830, 839, 843, 849, 855, 861 or 866, August 28 to September 10, 1930, 700 fathoms, and Net 1272, 1278, 1284, 1292, 1297, 1315 or 1327, September 7 to 19, 1931, 700 fathoms, are assigned to this species. Although they bear a striking resemblance to *A. curtirostris*, the completely carinated dorsal margin of the carapace and the absence of a long carina supporting the branchiostegal spine eliminates that species.

Despite the fact that the *Valdivia* obtained a specimen of *A. acutifrons* in a vertical net, one would guess that adults of this heavy-bodied species are largely benthonic and it is possible that only young individuals are usually encountered in midwater.

Geographical Distribution: Only two specimens of this species are recorded in the literature: the type from the Indian Ocean (Kemp believes the other specimens included under this species by Bate to be *A. curtirostris*) and the *Valdivia* specimen collected south of Sumatra. In addition, I have examined seven specimens taken by the *Albatross*, *Pawnee* and *Atlantis* in the Gulf of Mexico and the West Indian region.

***Acanthephyra eximia* Smith.**

Text-fig. 24.

Acanthephyra eximea Smith, 1884, p. 376; Smith, 1886, pl. 14, fig. 1.

Acanthephyra angusta Bate, 1888, p. 737, pl. 124, fig. 6.

Acanthephyra edwardsii Bate, 1888, p. 747, pl. 126, fig. 1.

Acanthephyra brachytelsonis Bate, 1888, p. 753, pl. 126, fig. 7.

Acanthephyra eximia Wood-Mason & Alcock, 1892, p. 361, fig. 3.

Acanthephyra brachytelsonis Wood-Mason & Alcock, 1892, p. 362, fig. 4.

Acanthephyra eximia Kemp, 1906, p. 20.

Acanthephyra eximea Chace, 1936, p. 27.

Acanthephyra eximia Calman, 1939, p. 191.

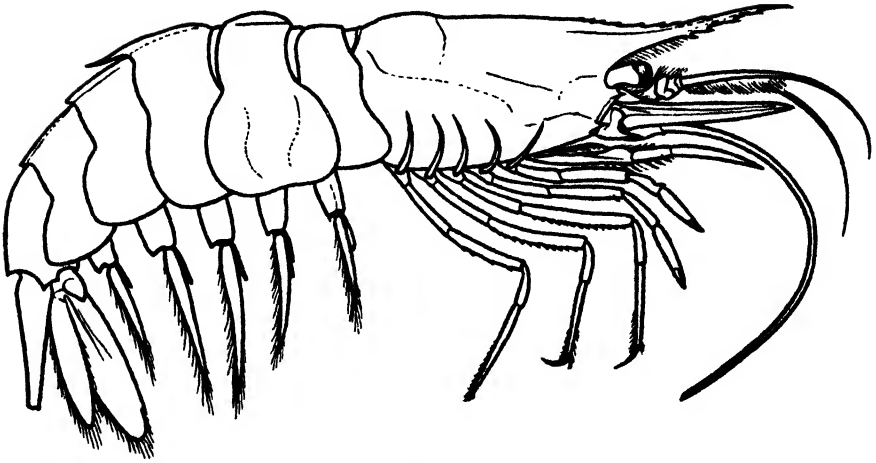
Diagnosis: Integument firm but not hard. Rostrum rather long and slender. Carapace dorsally carinate throughout its length. Branchiostegal spine not supported by a ridge. Abdomen carinate on all but the first somite and with a median posterior tooth or spine on the third, fourth, fifth and sixth somites, that of the third much the largest and those of the fourth and fifth often very small; telson faintly ridged dorsally and armed with from three to five pairs of lateral spinules.

Color in Life: Crimson (Alcock, 1901).

Remarks: Three specimens, all young, are referred to this species. One specimen with a carapace length of 8.9 mm. was taken in Net 257, 263, 269, 275, 281 or 288, July 5 to 11, 1929, from 800 fathoms; one specimen with a carapace length of 3.9 mm., from Net 427, 448, 462, 466, 467 or 476, September 5 to 13, 1929, from 900 fathoms; and one specimen with a carapace length of 5.2 mm. from Net 931, 935, 949, 962 or 969, September 22 to 30, 1930, from 800 fathoms.

This is another of that group of species which are apparently usually found on or near the bottom as adults.

There seems to be no excuse at the present time for separating *A. brachytelsonis* from this species, as the distinction between the two rests largely on the number of teeth on the lower margin of the rostrum. Apparently specimens having three teeth on the lower margin are commoner in the Pacific and those with four in the Atlantic, but the number varies from one to five, and I have seen one individual which was entirely devoid of ventral rostral teeth.



Text-figure 24.

Acantheephyra eximia. Holotype male (after Smith, 1886).
 × 1.03.

Calman, 1939, has pointed out that Smith, 1884, in one place in the original description used the correct form of the specific name, *eximia*, so it is probably advisable to regard the spelling, *eximeia*, as a *lapsus calami*.

Geographical Distribution: This is a widely distributed species, having been found in the western Atlantic off the coasts of North and South America and in the Indian and Pacific Oceans from off Cape Natal, Africa, to the Malay Archipelago, Japan and the Hawaiian and Society Islands. A few specimens were also taken by the *Challenger* near the Kermadec Islands. *A. eximia* seems to be most prevalent in the vicinity of land and has been found off most temperate and tropical coasts with the exception of the west coasts of the Americas and the west coasts of Europe and Africa. *Acantheephyra pulchra* A. Milne Edwards from the Mediterranean is probably a closely related form.

***Acantheephyra brevirostris* Smith.**

Text-fig. 25.

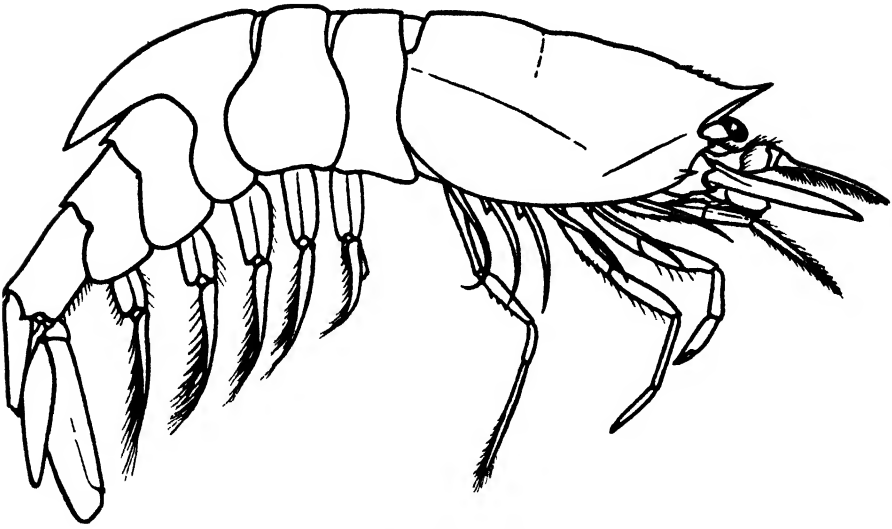
Acantheephyra brevirostris Smith, 1885, p. 504; Smith, 1886, p. 670 (66), pl. 14, fig. 2, pl. 15, figs. 2 and 8, pl. 16, figs. 1 and 6; Lenz & Strunck, 1914, p. 327.

Hymenodora duplex Bate, 1888, p. 843, pl. 136, fig. 3.

Diagnosis: Integument soft and almost membranous. Rostrum short. Carapace not dorsally carinate posteriorly. Branchiostegal spine not supported by a ridge. Abdomen carinate on all but the first two somites and with a median posterior tooth or spine on the third, fourth, fifth and sixth somites, that of the third extremely large and fleshy and usually overreaching the fourth somite; telson dorsally sulcate and armed with about five pairs of lateral spinules.

Color in Life: Unknown.

Remarks: This species, which is easily recognized by the large, fleshy spine on the third abdominal somite, is represented in the Bermuda collection by six specimens: a young male having a carapace length of 14.0 mm., and five young in which the carapace length varies from 5.5 to 9.0 mm. The young male was taken in June, July or August, 1931, from a depth of 1,000



Text-figure 25.

Acantheephyra brevirostris. Male from off Chesapeake Bay.
 × 1.55.

fathoms. The young were taken on the following dates: June 19, 1929, June 7, 1930, June 28 to July 4, 1930, September 13 to 19, 1930, and June 2 to August 5, 1931, in depths of 1,000, 1,000, 1,000, 700 and 900 fathoms respectively.

Examination of the mandible discloses that the incisor process is dentate throughout so that there is little doubt that this species is correctly assigned to the genus *Acantheephyra* and does not belong in the genus *Notostomus* as might be assumed from its soft integument and the fact that it has no close relatives among the species of the former genus.

It is not improbable that adults of *A. brevirostris* are usually found on, or close to, the bottom. At least it is evidently a deep-water form since no adults have been recorded from less than 1,000 fathoms.

Geographical Distribution: The majority of the recorded specimens of this species were taken off the east coast of the United States, but it has also been found in the Equatorial Atlantic, off Marion Island, southeast of the Cape of Good Hope and in the eastern Pacific off the coast of Ecuador.

***Acantheephyra gracillipes*, sp. nov.**

Text-figs. 26 and 27.

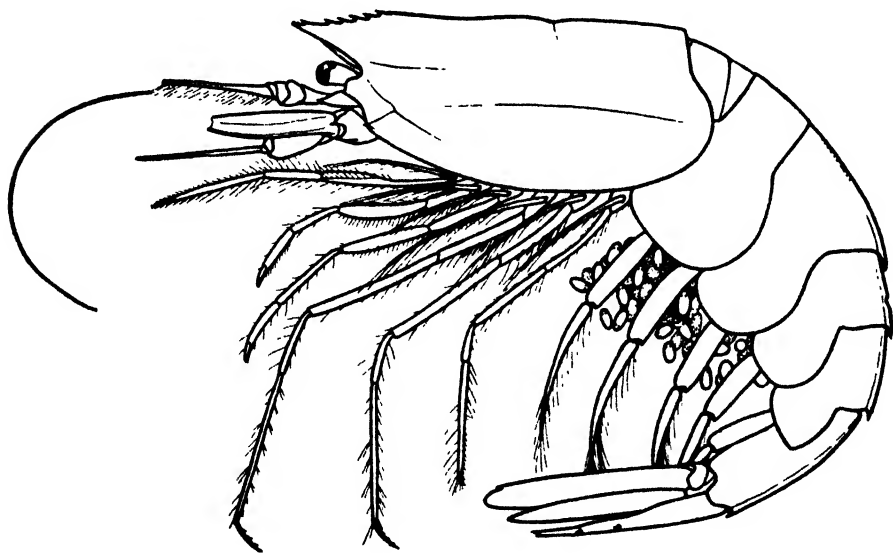
Type: Holotype ovigerous female, Cat. No. 301689 Department of Tropical Research, New York Zoological Society; Net 689 or 734; June 9 or 27, 1930; 1,000 fathoms.

Diagnosis: Integument very thin and fragile. Rostrum short. Carapace not dorsally carinate posteriorly. Branchiostegal spine not supported by a ridge or carina. Abdomen carinate on all but the first two somites and with a median posterior tooth on the third, fourth, fifth and sixth somites; telson dorsally sulcate.

Description: Carapace with a depression in the dorsal margin in the region of the cervical groove. Rostrum triangular, reaching about as far as the third segment of the antennular peduncle and armed dorsally with six

small teeth, two of which are behind the line of the orbit; there are no teeth or spines on the lower edge. The carina supporting the rostrum in the dorsal midline disappears before reaching the cervical groove. Antennal spine so minute as to be scarcely discernible. Branchiostegal spine much more prominent but without any supporting ridge or carina. The integument is so membranous that it is difficult to determine the distinctive grooves and ridges, but they apparently consist of an hepatic groove, a faint cervical groove passing over the dorsal midline and a distinct carina-like ridge above the branchial region passing backward from the hepatic region. Abdomen dorsally smoothly rounded on the first two somites, sharply carinate on the four following. Each of the latter four is provided with a prominent tooth, those of the third, fourth and fifth somites being offset to the left side of the animal as in *Notostomus compsus*. The end of the telson is missing; the remaining portion is dorsally sulcate and armed with two pairs of small spines. Eyes dark brown in alcohol and provided with a papilla on the inner surface just behind the cornea. Antennal scales broken. Third maxillipeds and all of the pereopods very long and slender; the third pereopods, which are the longest, exceed the antennal scale by the dactyl and probably nearly half of the propodus.

In the single specimen, the eggs were apparently nearly ready to hatch as evidenced by the presence of eye spots.



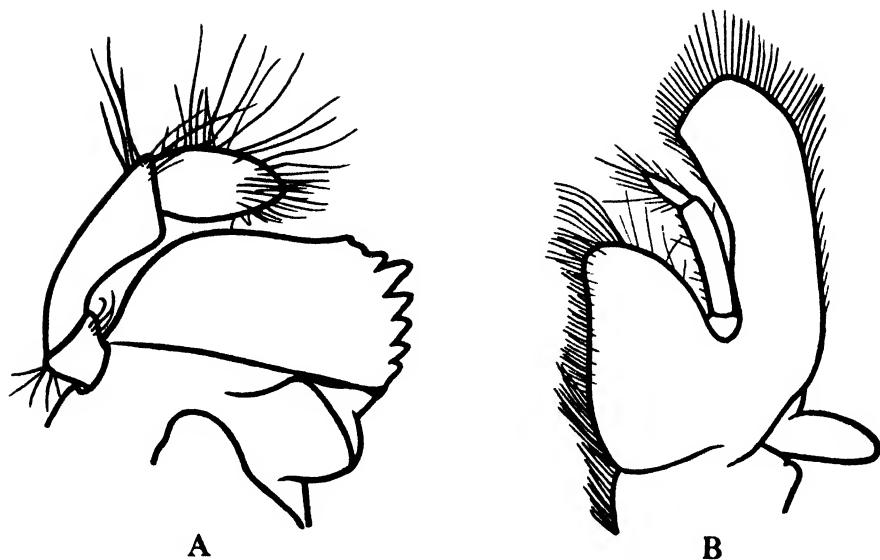
Text-figure 26.

Acantheephyra gracilipes. Holotype ovigerous female. $\times 3.49$.

Measurements: Total length about 42 mm.; length of carapace, 12.4 mm.; length of rostrum, 2.6 mm. The eggs measure about 0.8 mm. in longer diameter.

Color in Life: Unknown.

Remarks: *A. gracilipes* belongs to that group of the genus comprising *A. sibogae* de Man, 1916, *A. cucullata* Faxon, 1893, *A. tenuipes* (Bate, 1888) and *A. indica* Balss, 1925. All of the species of this group have a more or less membranous integument and closely resemble the less specialized



Text-figure 27.

Acanthephyra gracilipes. A. Mandible. B. First maxilliped.

members of the genus *Notostomus*, so much so that their generic status cannot easily be determined except by examination of the mandibles. *A. sibogae* differs from *A. gracilipes* by having the carapace dorsally carinate throughout its length, by having no antennal spine, the branchiostegal spine supported by a carina and no spine or tooth on the third abdominal somite. *A. cucullata* has a much higher and shorter rostrum, the branchiostegal spine supported by a long carina and the second abdominal somite dorsally carinate. *A. tenuipes* more closely resembles *A. gracilipes* and it is difficult from Bate's description and figure to make a very definite comparison with the present species; apparently, however, in *A. tenuipes* the rostrum is higher and somewhat more compressed laterally and (Bate's figure to the contrary) the fourth, fifth and sixth abdominal spines are less prominent than those of *A. gracilipes*. Finally, *A. indica*, which closely resembles the Bermuda species in general form, can be distinguished by the presence of a branchiostegal carina, a carina on the dorsal margin of the second abdominal somite and probably by a much shorter telson. *A. gracilipes* probably has longer and more slender pereopods than any of the other species of the group.

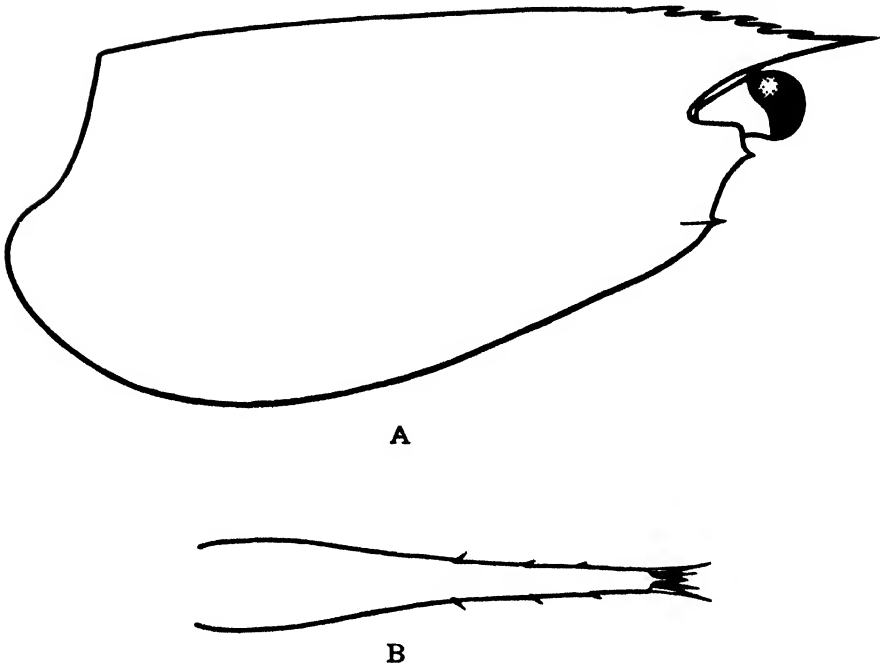
***Acanthephyra*, sp. ?**

Text-fig. 28.

Diagnosis: Integument thin and soft. Rostrum short. Carapace not dorsally carinate posteriorly. Branchiostegal spine supported by a very short carina. Abdomen carinate on all but the first two somites and with, or without, a small posterior spine on the fifth and sixth somites, telson dorsally sulcate and armed with three pairs of lateral spinules.

Color in Life: Unknown.

Remarks: Eight specimens, ranging in size from a carapace length of 3.8 to 5.8 mm., belong to this undetermined species. They were taken in



Text-figure 28.

Acanthephyra, sp. ?. A. Carapace of specimen taken in June, July or August, 1931, from 1,000 fathoms. B. Telson of same specimen.

June, 1929, June to September, 1930, and June to September, 1931, in 900 and 1,000 fathoms. Since none of the specimens are ovigerous or have an appendix masculina on the second pleopods, it is very likely that they are immature. They most closely resemble *A. rostrata* (Bate, 1888) and may prove to be the young of that species, but they differ from Bate's description and figure in that they have fewer rostral teeth and no long carina-like ridge supporting the branchiostegal spine. The fact that the larger specimens have a small tooth at the end of the sixth abdominal somite and the largest also has a small tooth on the fifth somite indicates that possibly the dentition of the abdominal somites may be further developed in adult individuals if, indeed, the present specimens are actually young.

Genus *Notostomus* A. Milne Edwards, 1881a.

Carapace with at least one straight carina running along the median lateral line from the orbital region to the hind margin, and with an oblique carina delimiting the hind margin of the hepatic furrow. Abdomen carinate on the last four somites, at least. Telson more or less truncate at the tip, not terminating in a sharply pointed end-piece laterally armed with spines. Pereiopods not abnormally broad and flattened. Exopods of third maxillipeds and pereiopods neither foliaceous nor rigid. Eyes well pigmented even when small. Outer margin of antennal scale not armed with a series of spines. Incisor process of mandible toothed for only half the length of the cutting edge.

KEY TO THE BERMUDIAN SPECIES OF *Notostomus*.

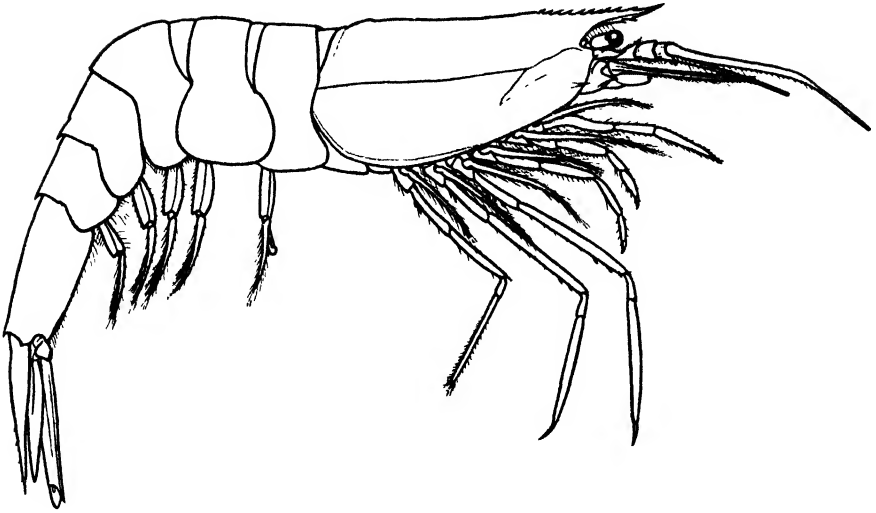
1. A single longitudinal carina on lateral surface of carapace; dorsal margin of carapace not denticulate on posterior three-fourths of its length; abdomen not dorsally carinate on first somite 2.
 More than one longitudinal carina on lateral surface of carapace; dorsal margin of carapace denticulate for nearly its entire length; abdomen dorsally carinate on every somite 6.
2. No posterior tooth or spine on third abdominal somite 3.
 A posterior tooth or spine on third abdominal somite 5.
3. Integument firm; eyes at least as broad as eyestalks in lateral view 4.
 Integument extremely soft and fragile; eyes much narrower than eyestalks *N. mollis*
4. Sixth abdominal somite about twice as long as fifth; second abdominal somite not dorsally carinate *N. vescus*
 Sixth abdominal somite little longer than fifth; second abdominal somite dorsally carinate *N. compsus*
5. Posterior tooth on third abdominal somite broad and truncate or concave distally; dactyls of chelipeds terminating in two small, blunt spines; size very small *N. miccylus*
 Posterior tooth on third abdominal somite triangular like those on following somites; dactyls of chelipeds terminating in two long, slender spines; size moderately large *N. marptocheles*
6. Not more than two prominent longitudinal carinae on lateral surface of carapace *N. distirus*
 Four or five longitudinal carinae on posterior half of lateral surface of carapace 7.
7. Four longitudinal carinae on posterior half of lateral surface of carapace. 8.
 Five longitudinal carinae on posterior half of lateral surface of carapace *N. westergreni* ?
8. Post-orbital not continuous with rostral carina *N. robustus*
 Post-orbital continuous with rostral carina *N. perlatus* ?

***Notostomus vescus* Smith.**

Text-figs. 29 and 30.

Notostomus vescus Smith, 1886, p. 677 (72).*Acanthephyra brevirostris* Bate, 1888, p. 751, pl. 126, figs. 5-6. (Not *Acanthephyra brevirostris* Smith, 1885).*Acanthephyra batei* Faxon, 1895, p. 167.*Acanthephyra batei* Hansen, 1908, p. 77, pl. 4, fig. 2a.*Notostomus batei* Balss, 1925, p. 267.*Notostomus vescus* Chace, 1936, p. 28.

Diagnosis: Integument soft, but not so fragile that the body easily loses its shape. Carapace not inflated, dorsal margin in line with rostrum and not dentate on posterior three-fourths of its length. A single lateral carina on carapace passing from orbit to hind margin. Branchiostegal spine without a carina. Rostrum usually with one or two ventral teeth in addition



Text-figure 29.

Notostomus vascus. Male taken in June, July or August, 1931, from 700 fathoms. $\times 2.91$.

to the dorsal series. Abdomen carinate only on the third, fourth, fifth and sixth somites and with a posterior tooth on the fourth, fifth and sixth; sixth somite about twice as long as fifth. Eyes at least as broad as eye-stalks. Dactyls of first two pairs of pereipods ending in two short spines, one of which falls on either side of the fixed finger when fingers are closed.

Measurements: The smallest recognizable males have a carapace length of about 8.0 mm. The largest male has a carapace measuring 18.0 mm. The largest female gives a corresponding measurement of 16.7 mm. and the smallest ovigerous female, 13.0 mm. The youngest specimen has a carapace 4.3 mm. long.

Color in Life: Of this species, Hansen, 1908, writes, "The carapace is greenish, lighter or darker chiefly according to the colour of the tissues underneath. The dorsal aspect of the first three abdominal segments is gray-green, the lateral surfaces much lighter." Although no color notes were made upon specimens of this species in the Bermuda material, I cannot help but feel that Hansen's specimen may have attained this coloration artificially, possibly from being kept in a copper container which will often affect specimens in this way. I have seen living specimens of this species and, although no color notes were taken, my impression is that the animal was a very dark, dull crimson, the carapace being somewhat darker than the abdomen and very much darker than other bathypelagic forms commonly met with.

General Remarks: This species is represented by 152 specimens; 28 males, 50 females, of which 15 are ovigerous, and 74 young. Seven of the ovigerous specimens are carrying eggs in which the eyes are visible.

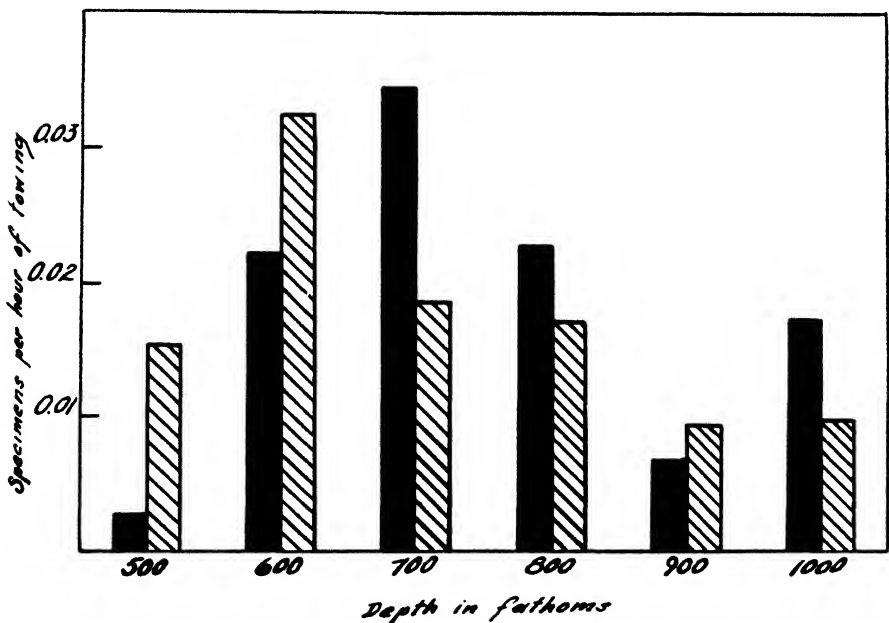
An examination of Smith's type of *Notostomus vascus* in the U. S. National Museum leaves little doubt that *Acanthephyra brevirostris* Bate (= *A. batei* Faxon) is a synonym of Smith's species.

Out of 123 of the Bermuda specimens in which the rostrum was examined, 5 have no ventral rostral teeth, 84 have one such tooth, 32 have two and 2 have three. In several of the very young specimens, the posterior spine on the fourth abdominal somite is minute and sometimes entirely absent.

Seasonal Distribution: Any conclusions as to seasonal distribution based on such a small number of specimens must be accepted with caution. Both adults and young were taken in every month from April to September in 1929 and 1930. Ovigerous females were found in April, May, June, July and August, and those in which the eggs were eyed occurred in May, June, July and August. It is of interest that of the thirteen females taken in September none were carrying eggs, whereas out of a like number taken in June six were ovigerous. If one examines the proportion of specimens carrying eyed eggs out of the number of ovigerous females taken in each month, it is found that the single ovigerous specimen taken in April did not carry eyed eggs, of four taken in May the eggs of one were eyed, of six in June three were eyed and the single ovigerous specimen taken in August carried eyed eggs. One might theorize from this that the eggs usually hatched in June or July, but much more material would have to be accumulated before such a hypothesis could be verified. It will be noted that the total catch contained nearly twice as many females as males. This dissimilarity is found to hold true for every month in which towing was done with the possible exception of September, in which month eleven of the twenty-four adults taken were males.

Vertical Distribution: The following table shows the vertical distribution of the total catch of *N. vascus*:

Fathoms	Males	Females	Young
500.....	1.....	1.....	11.....
600.....	4.....	11 (4 ovig.).....	22.....
700.....	10.....	14 (3 ovig.).....	13.....
800.....	6.....	10 (2 ovig.).....	12.....
900.....	4.....	1 (ovig.).....	7.....
1,000.....	3.....	13 (5 ovig.).....	9.....



Text-figure 30.

Vertical distribution of adults (solid bars) and young (hatched bars) of *Notostomus vascus*.

These data, correlated with the towing time at each depth, are shown in Text-fig. 30. The optimum level for adults appears to be at about 700 fathoms, and for the young at about 600 fathoms. All of these specimens were taken in the daytime. It is difficult to explain the increase in numbers of adults at 1,000 fathoms, but a smooth distribution curve is hardly to be expected with so few individuals and with the use of open nets. Ovigerous females carrying eyed eggs were taken at 600, 700, 800, 900 and 1,000 fathoms, one at each of the first four levels and three at 1,000 fathoms.

Geographical Distribution: *N. vescus* has been recorded from the North Atlantic south of Iceland, off the east coast of the United States, in mid-Atlantic near the equator and in the Bay of Bengal. I have also seen specimens from the Philippine region.

***Notostomus compsus*, sp. nov.**

Text-figs. 31 and 32.

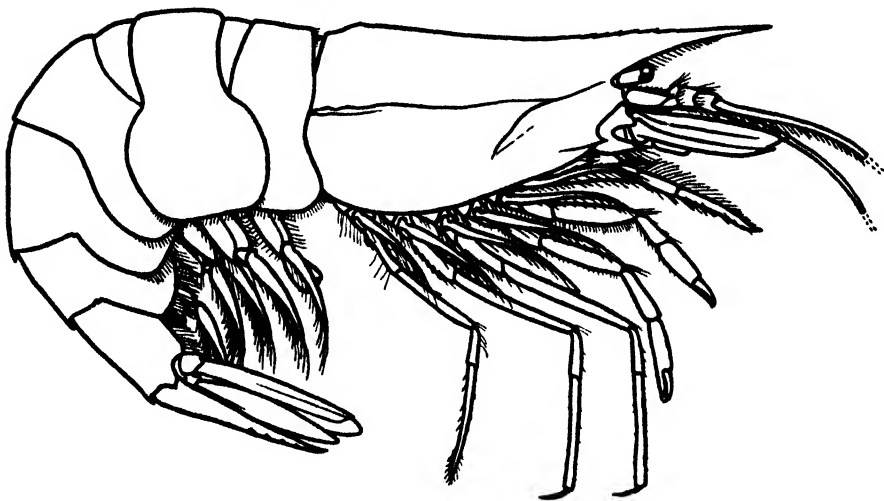
Types: Holotype male, Cat. No. 30,322, Department of Tropical Research, New York Zoological Society; Net 748; June 30, 1930; 900 fathoms.

One ovigerous female; Net 421; September 4, 1929; 1,000 fathoms.

One ovigerous female; Net 552; May 9, 1930; 600 fathoms.

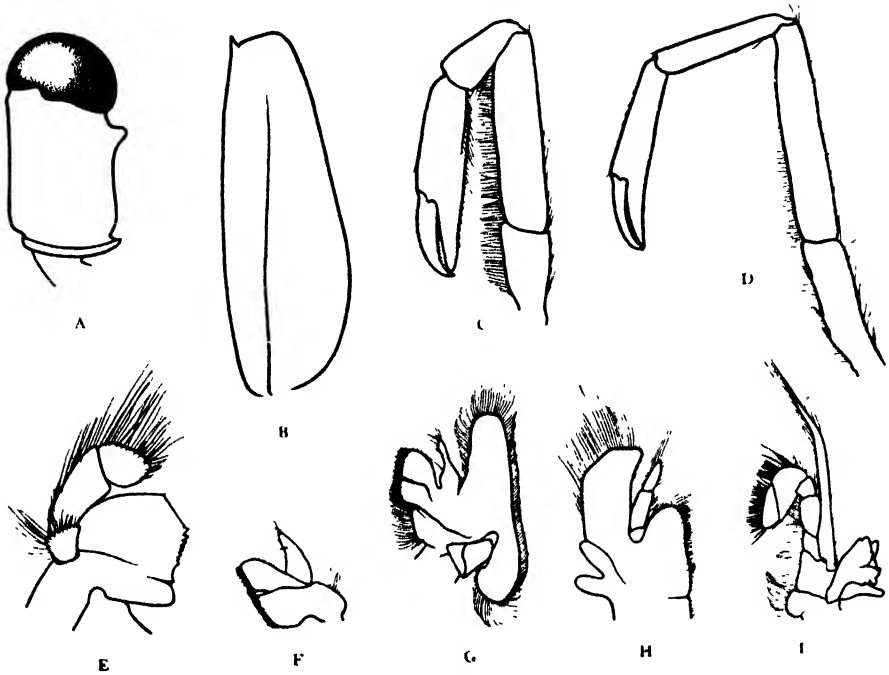
Diagnosis: Integument firm but not hard. Carapace not inflated; dorsal margin in line with rostrum and not dentate on posterior three-fourths of its length. A single lateral carina on carapace passing from orbit to hind margin. Branchiostegal spine supported by a short ridge. Rostrum without teeth or spines on lower margin. Abdomen carinate on all but the first somite, but that of the second is indistinct; a posterior spine on the fourth, fifth and sixth somites; sixth somite little longer than fifth. Eyes as broad as eyestalks, dactyl of first two pairs of pereopods with a minute spine far back from the tip.

Description: Carapace dorsally sharply carinate for nearly its entire length; this carina is somewhat concave in the central portion and rises slightly anteriorly to an acutely triangular rostrum which reaches beyond the antennular peduncles but not quite as far as the tips of the antennal



Text-figure 31.

Notostomus compsus. Holotype male. $\times 1.32$.



Text-figure 32.

Notostomus compsus. A. Left eye from above. B. Antennal scale. C. First pereopod. D. Second pereopod. E. Mandible. F. First maxilla. G. Second maxilla. H. First maxilliped. I. Second maxilliped.

scales. There is a series of about six minute teeth at the base of the rostrum, two of them being behind the line of the orbit, but the anterior third of the rostrum is unarmed. There is no armature on the lower margin. A single lateral carina passes back from the orbit to the hind margin and the usual carina marking the posterior limit of the hepatic furrow is present. Branchiostegal spine supported by a short ridge which disappears before reaching the hepatic furrow. First somite of abdomen smoothly rounded dorsally; second somite with a very faint carina, and this carina increases in importance on each succeeding somite. Third somite unarmed; fourth, fifth and sixth somites with a median posterior spine, those on the fourth and fifth offset to the left side of the mid-line. Sixth somite about one-fifth again as long as the fifth. Telson slightly shorter than the combined lengths of the fifth and sixth somites, deeply sulcate dorsally, armed with four or five pairs of lateral spinules and truncate at the end. Eyes brown in alcohol and about as broad as the stalks; there is a small papilla on the inner side of the stalk. Stylocerite reaches to the end of the first segment of the antennular peduncle. Antennal scale broad with a broad, truncate tip, the inner angle of which overreaches the outer spines. Third maxillipeds extend about to the end of the antennal scales. The fingers of the first two pairs of pereopods close normally, although there is a minute tooth back of the terminal spine of the movable finger. The eggs are proportionately very small, about 1.0 mm. in diameter, nearly spherical and very numerous.

Measurements: Total length of holotype about 112 mm.; length of carapace 28.7 mm.; length of rostrum 15.6 mm.

The ovigerous female from Net 421 has a carapace length of 27.0 mm., and the one from Net 552, 32.2 mm.

Color in Life: Unknown.

Remarks: Except for its much larger size, this species might easily be confused with *N. vesus*. It differs from that species by apparently never having any ventral spines or teeth on the rostrum, by having the branchiostegal spine buttressed by a sharp ridge, by having the spines of the fourth and fifth abdominal somites offset to the left and, finally, by having the sixth abdominal somite very little longer than the fifth, rather than about twice as long as in *N. vesus*. *N. compsus* may be readily separated from *N. mollis*, the only other described species of the genus which lacks a spine on the third abdominal somite, by its much firmer integument, more slender carapace, longer rostrum and larger eyes.

***Notostomus marptocheles*, sp. nov.**

Text-figs. 33 and 34.

Types: Holotype female, Cat. No. 1060, Bingham Oceanographic Collection, Yale University; *Atlantis* Station 1478; lat. 25° 29' N., long. 77° 18' W.; N. E. Providence Channel, Bahamas; February 20, 1933; 875 fathoms of wire.

One young; *Pawnee* Station 46; lat. 21° 46' N., long. 72° 50' W.; north of Little Inagua Island, Bahamas; April 4, 1927; 1,667 fathoms of wire.

One ovigerous female, one young; *Pawnee* Station 48; lat. 21° 44' N., long. 72° 43' W.; north of Little Inagua Island, Bahamas; April 6, 1927; 1,167 fathoms of wire.

One young; D.T.R. Net 81; May 8, 1929; 900 fathoms.

One young; Net 138 (?), 143, 149, 154, 161, 167, 173, 179, 185 (?), 190 or 196; May 30 to June 20, 1929; 800 fathoms.

One young; Net 247; July 1, 1929; 1,000 fathoms.

One ovigerous female; Net 365; August 10, 1929; 1,000 fathoms.

Two young; Net 496 (?) or 516; September 23 or 27, 1929; 1,000 fathoms.

One young; Net 716, 740 or 761; June 17 to July 2, 1930; 900 fathoms.

One young male; Net 726 (?), 733 or 771; June 26 to July 4, 1930; 900 fathoms.

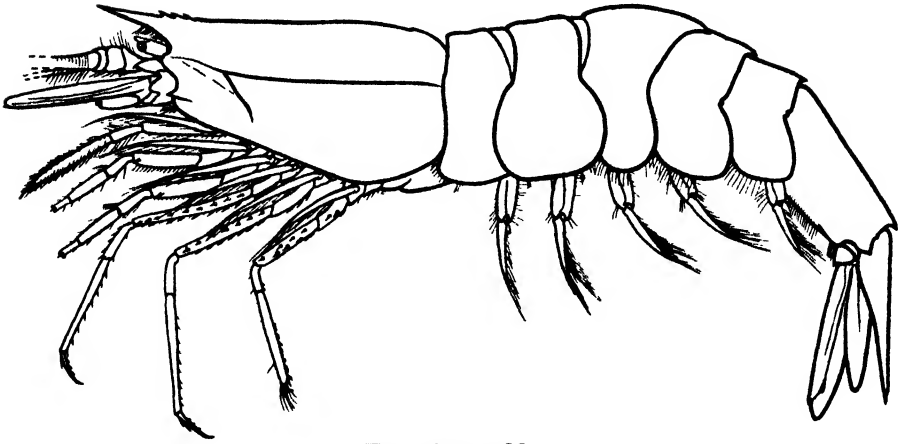
One young; Net 827 or 858; September 1 or 6, 1930; 1,000 fathoms.

One young male; Net 983 (?), 993, 1001, 1007, 1024, 1025, 1105, 1114 (?), 1116, 1124 or 1134; June 2 to August 5, 1931; 800 fathoms.

One female; Net 1165, 1166, 1171, 1178, 1185, 1190, 1203, 1204, 1207, 1208, 1213, 1219, 1230, 1239, 1245, 1251, 1258 or 1264; August 11 to September 4, 1931; 900 fathoms.

Diagnosis: Integument firm but not hard. Carapace not inflated, dorsal margin in line with rostrum and not dentate on posterior three-fourths of its length. A single lateral carina on carapace passing from orbit to hind margin. Branchiostegal spine supported by a very short carina. Rostrum without teeth or spines on lower margin. Abdomen carinate on all but the first somite, but the carina of the second is extremely indistinct; a posterior spine on the third, fourth, fifth and sixth somites; sixth somite more than twice as long as fifth. Eyes nearly as broad as eyestalks. Dactyls of first two pairs of pereopods ending in two long spines, one of which falls on either side of the fixed finger when fingers are closed.

Description: Carapace dorsally sharply carinate for its entire length; this carina is nearly straight throughout and in line with the dorsal margin of the rostrum. The latter is acutely triangular and reaches just beyond the end of the antennular peduncle; it is armed with two to five, usually three or four, dorsal spines at the base, one or two being placed behind the line of



Text-figure 33.

Notostomus marptocheles. Holotype female. $\times 2.03$.

the orbit, but the distal third, at least, is unarmed dorsally and there are no teeth or spines on the lower margin. A single lateral carina passes from the orbit to the hind margin, and the usual carina delimiting the hepatic furrow posteriorly is present. Branchiostegal spine supported by a sharp carina which is only three or four times as long as the spine, itself. First somite of abdomen smoothly rounded dorsally. Second somite with an almost invisible line representing a dorsal carina. Succeeding four somites with a sharp dorsal carina ending posteriorly in a prominent tooth, those of the third, fourth and fifth folded over to the left (Text-fig. 34A). Sixth somite slightly more than twice as long as the fifth. Telson about as long as the sixth somite, dorsally sulcate on the distal half, armed with four pairs of lateral spines along the margin of the sulcus and more or less truncate at the tip, with three spines on either side of a median one. Eyes nearly as wide as the dorso-ventral diameter of the stalk; there is a prominent papilla arising from the inner surface of the stalk and extending at least as far as the tip of the cornea. Stylocerite does not reach the end of the first segment of the antennular peduncle. Antennal scale tapering to a rounded end which is slightly surpassed by the outer spine. Third maxillipeds extend about as far as the antennal scales. Dactyls of chelae of first two pereopods terminate in two long, curved spines, between which the fixed finger fits when the fingers are closed (Text-fig. 34E-F). Meri of last three pereopods spiny. Eggs proportionately small, about 1.1 mm. in longer diameter, broadly oval and numerous.

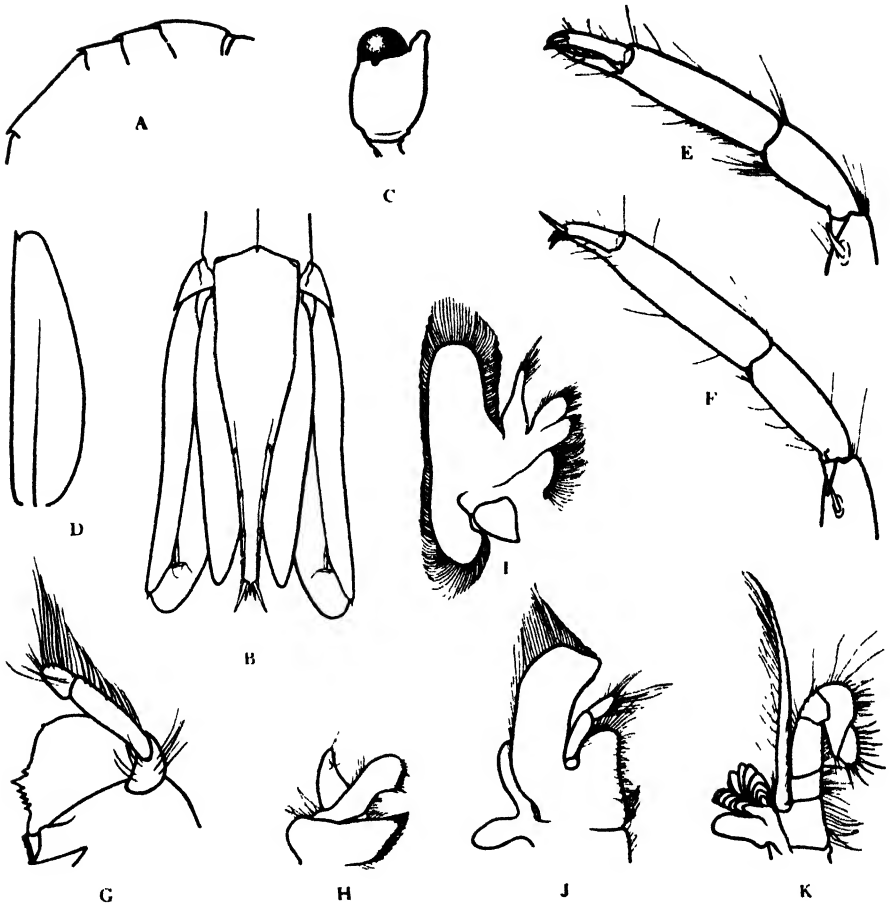
Measurements: Total length of holotype about 62 mm.; length of carapace 17.2 mm.; length of rostrum 4.9 mm.

The two young males, in which the appendix masculina is shorter than the other stylet, have the carapace 17.0 mm. long in each. The two ovigerous females have a carapace length of 20.1 and 22.8 mm., and the latter is the largest specimen examined. The smallest specimen has a carapace length of 5.5 mm.

Color in Life: Deep scarlet—nearly black. Rostrum and mouth parts bright red.

Remarks: Inasmuch as the specimens from the Bingham Oceanographic Collection were sent for identification before the Bermuda collection, Dr. Beebe has kindly consented to the selection of the holotype from that series.

It will be seen from the net data that *N. marptocheles* was found at



Text-figure 34.

Notostomus marptocheles. A. Dorsal margins of third, fourth, fifth and sixth abdominal somites viewed from the right side. B. Telson and uropods. C. Left eye from above. D. Antennal scale. E. Carpus and hand of first pereopod. F. Carpus and hand of second pereopod. G. Mandible. H. First maxilla. I. Second maxilla. J. First maxilliped. K. Second maxilliped.

Bermuda in every month of the year in which towing was done with the exception of April. Apparently it is a relatively deep water species, since two specimens were taken in 800 fathoms, four in 900 and five in 1,000. The eggs on the ovigerous female from *Pawnee* Station 48 were eyed, whereas those on the Bermuda specimen from Net 365 were not.

Although this species bears a close resemblance to *N. compsus*, it may be readily distinguished by the presence of a spine on the third abdominal somite, the much longer sixth somite, differently formed eyes and antennal scales and the long terminal spines on the movable fingers of the chelipeds.

Apparently most, if not all, of the species of Oplophoridae have the dactyls of the chelipeds more or less split at the end for the reception of the fixed finger when the fingers are closed, but in no others that I have seen are these terminal spines so long as to be easily visible to the naked eye.

***Notostomus miccylus*, sp. nov.**

Text-figs. 35-37.

Types: Holotype female, Cat. No. 1061, Bingham Oceanographic Collection, Yale University; *Pawnee* Station 48; lat. 21° 44' N., long. 72° 43' W.; north of Little Inagua Island, Bahamas; April 4, 1927; 1,167 fathoms of wire.

Two males: *Pawnee* Station 11; lat. 23° 58' N., long. 77° 26' W.; Tongue of the Ocean, Bahamas; March 2, 1927; 1,167 fathoms of wire.

One female: *Pawnee* Station 25; lat. 24° 51' N., long. 76° 37' W.; Exuma Sound, Bahamas; March 17, 1927; 1,333 fathoms of wire.

Two females (one ovigerous): *Pawnee* Station 52; lat. 21° 30' N., long. 71° 11' W.; Turks Island Passage; Bahamas; April 11, 1927; 1,333 fathoms of wire.

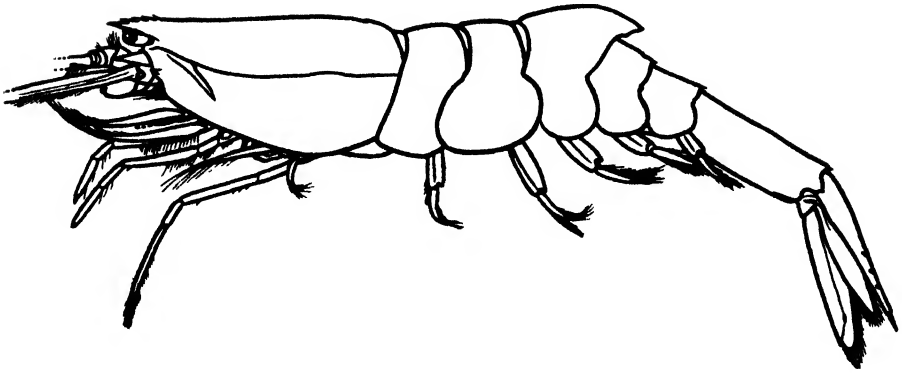
One female: *Pawnee* Station 58; lat. 32° 24' N., long. 64° 29' W.; off Bermuda; April 20, 1927; 833 or 1,667 fathoms of wire.

Two females: *Atlantis* Station 1478; lat. 25° 29' N., long. 77° 18' W.; N.E. Providence Channel, Bahamas; February 20, 1933; 875 fathoms of wire.

47 males, 73 females (4 ovigerous), 25 young; D.T.R. Bermuda Expeditions; 1929 to 1931; 500 to 1,000 fathoms.

Diagnosis: Integument thin but not membranous. Carapace not inflated, dorsal margin in line with rostrum and not dentate on posterior nine-tenths of its length. A single lateral carina on carapace passing from orbit to hind margin. Branchiostegal spine not supported by a carina. Rostrum without teeth or spines on lower margin. Abdomen carinate on all but first somite but the carina of the second is hardly visible; a posterior spine on third, fourth, fifth and sixth somites, that on the third being very broad with a concave distal margin; sixth somite more than two and one-half times as long as fifth. Eyes as broad as eye-stalks. Dactyl of first two pairs of pereopods ending in two small, blunt spines.

Description: Carapace dorsally sharply carinate for its entire length; the carina is nearly straight and continuous with the dorsal margin of the rostrum. Rostrum acutely triangular and not reaching beyond the second segment of the antennular peduncle; it is armed with from two to six, usually three to five, dorsal spines at the base, one sometimes being placed behind the line of the orbit; there are no teeth or spines on the lower margin. Of 135 specimens in which the rostrum is undamaged, one specimen has two dorsal rostral spines, 19 have three, 71 have four, 40 have five and four have six. A single lateral carina runs from the orbit to the hind margin of the carapace, and there is the usual carina delimiting the hepatic furrow posteriorly. Branchiostegal spine outstanding but not supported by any carina or sharp ridge. First abdominal somite smoothly rounded dorsally. Second somite with a faint line representing a dorsal carina. The next four somites are sharply carinate. The third somite is provided with a distinctive broad tooth which is truncate or concave distally. Fourth, fifth and sixth somites end in a small, sharp spine. Sixth somite more than two and one-half times as long as the fifth. Telson slightly longer than the sixth somite, deeply sulcate dorsally, armed with three or four pairs of dorso-lateral spinules and with a more or less truncate tip which bears three spines on either side of a central one. Eyes nearly black and about as wide as the dorso-ventral width of the stalk; in dorsal view, the stalk is much wider than the cornea and bears a small, rounded papilla on the inner margin. Stylocerite narrow and drawn out to a slender point which reaches just beyond the first segment of the antennular peduncle. Antennal scale narrow, sharply concave along its external margin and truncate distally, the outer spine extending beyond the blade. Third maxillipeds extend about as far as the antennal scales. All of the pereopods are normal. The eggs are small.



Text-figure 35.

Notostomus miccylus. Holotype female. $\times 338$.

Measurements: Total length of holotype about 33 mm.; length of carapace 9.2 mm.; length of rostrum 2.0 mm.

The smallest recognizable male has a carapace length of 4.9 mm. The ovigerous females have carapace lengths ranging from 7.2 to 9.5 mm. In this species the female apparently attains a larger size than the male; females reach a carapace length of 10.0 mm., whereas the largest male examined had a carapace measurement of only 8.1 mm. The smallest specimens seen have the carapace 3.2 mm. long.

Color in Life: Abdomen solid scarlet; cephalothorax and telson heavily dotted with scarlet. Eyes dark brown.

General Remarks: Inasmuch as the specimens from the Bingham Oceanographic Collection were sent for identification before the Bermuda collection, Dr. Beebe has kindly consented to the selection of the holotype from that series.

Although this species might be confused with *N. vescus* because of the similarity in size, *N. miccylus* is even smaller than *N. vescus* and can be distinguished from it and all other known species of the genus by the characteristic shape of the tooth on the third abdominal somite.

Seasonal Distribution: The seasonal distribution of the population of *N. miccylus* over the months in which tows were made in 1929 and 1930 is shown in the following table:

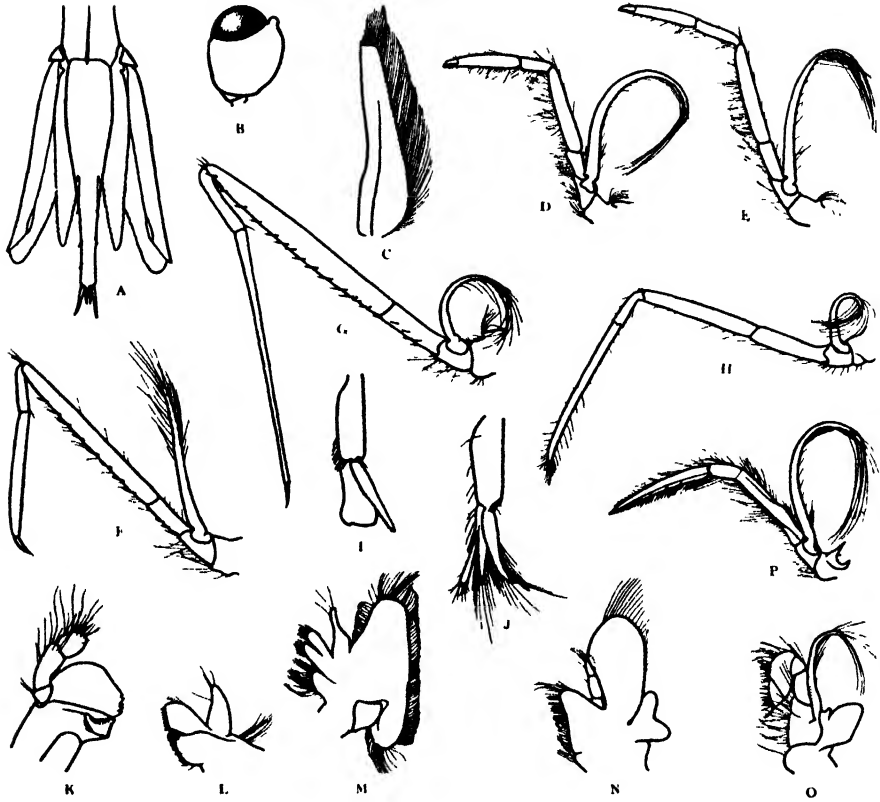
1929

April	.....	3 females (1 ovig.), 2 young
May	.....	1 male, 2 females, 1 young
June	.....	1 male, 12 females, 1 young
July	.....	6 males, 14 females (2 ovig.), 3 young
August	.....	1 male, 3 females, 1 young
September	.....	8 males, 9 females, 2 young

1930

May	.....	4 males, 1 female, 1 young
June	.....	6 males, 5 females, 3 young
July	.....	3 males, 4 females, 2 young
August	.....	1 male
September	.....	4 males, 8 females (1 ovig.), 1 young

It will be noted that the distribution over these months is reasonably uniform and that ovigerous females were taken in April, July and September. Curiously, each of the four ovigerous specimens carried but one egg and there was evidence that the remaining eggs had recently hatched;



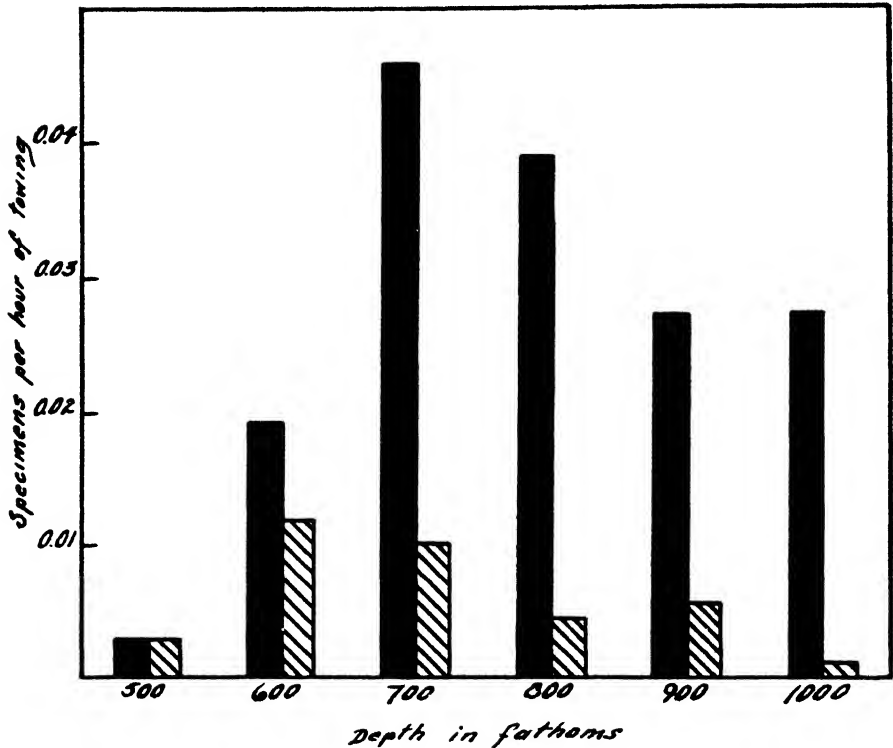
Text-figure 36.

Notostomus miccyllus. A. Telson and uropods. B. Left eye from above. C. Antennal scale. D. First pereopod. E. Second pereopod. F. Third pereopod. G. Fourth pereopod. H. Fifth pereopod. I. First pleopod of male. J. Second pleopod of male. K. Mandible. L. First maxilla. M. Second maxilla. N. First maxilliped. O. Second maxilliped. P. Third maxilliped.

the remaining egg was eyed and obviously ready to hatch in three of the specimens and in the other, taken in September, 1930, the egg was not eyed and was possibly infertile. Whether the fact that only about 5 per cent. of the adult females carried eggs and in those few most of the eggs were missing indicates that the Bermuda area is not included in the normal "breeding range" is problematical. The table also discloses the anomaly that in 1929 only about 28 per cent. of the adult specimens were males, while in 1930 there were like numbers of each sex.

Vertical Distribution: The vertical distribution of the total catch of *N. miccyllus* is shown in the following table:

Fathoms	Males	Females	Young
500.....	1.....	1.....	2.....
600.....	6.....	7 (1 ovig.).....	8.....
700.....	15.....	17 (1 ovig.).....	7.....
800.....	7.....	20.....	3.....
900.....	8.....	12 (1 ovig.).....	4.....
1,000.....	9.....	16 (1 ovig.).....	1.....



Text-figure 37.

Vertical distribution of adults (solid bars) and young (hatched bars) of *Notostomus miccyllus*.

These data, correlated with the towing times, are shown in Text-fig. 37. All of these specimens were taken in the daytime. A close parallelism between the vertical range of this species and that of the other small species of the genus, *N. vescus*, will be noted.

***Notostomus mollis* (Smith).**

Text-fig. 38.

Meningodora mollis Smith, 1882, p. 74, pl. 11, figs. 8-9, pl. 12, figs. 5-9.

Hymenodora mollis Bate, 1888, p. 841, pl. 136, fig. 5.

Notostomus fragilis Faxon, 1893, p. 207; 1895, p. 170, pl. 44, figs. 2-2b.

Notostomus mollis Balss, 1925, p. 266, fig. 37 (mandible).

Diagnosis: Integument extremely soft and fragile. Carapace somewhat inflated, dorsal margin evenly convex from rostrum to hind margin and not dentate on posterior nine-tenths of its length. A single lateral carina on carapace passing from orbit nearly to hind margin. Branchiostegal spine supported by a short sharp ridge or carina. Rostrum without spines on lower margin. Abdomen carinate on third, fourth, fifth and sixth somites only, and with a posterior tooth on fourth, fifth and sixth; sixth somite about one and two-thirds times as long as fifth. Eyes narrower than eyestalks. Dactyls of first two pairs of pereopods ending in two small, blunt, unequal teeth between which the fixed finger lies when the fingers are closed.

Measurements: A young male, in which the appendix masculina of the second pleopods is rudimentary, has a carapace length of 17.0 mm. The largest male has the carapace 23.0 mm. long, the largest female 24.2 mm. and the single ovigerous female 23.4 mm. The smallest specimen has a carapace length of 4.2 mm. The eggs are 0.9 mm. in greater diameter.

Color in Life: Cephalothorax maroon-tinged black shading to nopal red on the abdomen. Antennae, thoracic epipods and pleopods all nopal red. Thoracic legs dark maroon shading to lighter toward their tips. Eyes blackish.

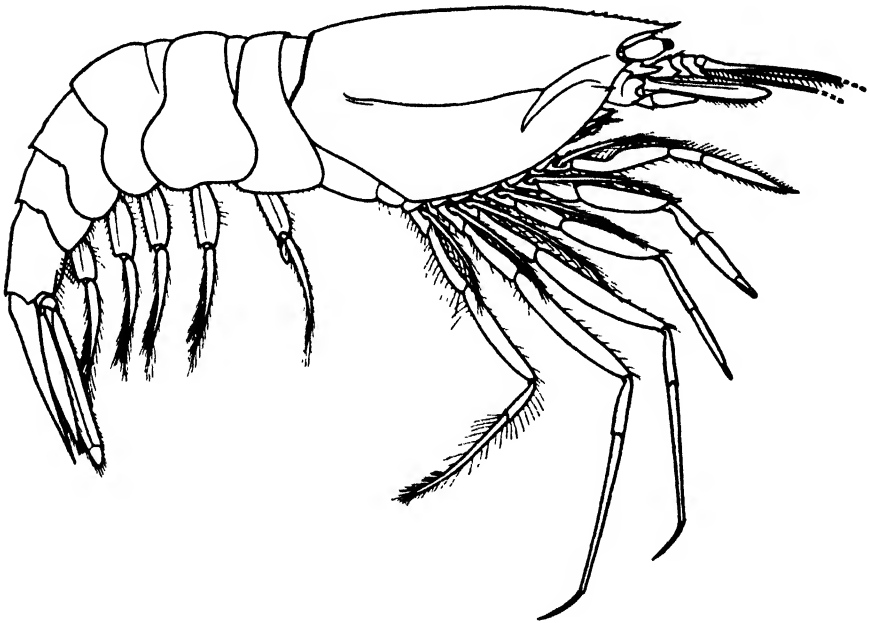
General Remarks: The collection contains 56 specimens of this species; 2 males, 10 females, of which 1 is ovigerous, and 44 young. The eyes are visible in the eggs of the single ovigerous specimen.

N. mollis may be distinguished from the other members of the genus in which the carapace is not markedly inflated and the first abdominal somite uncarinated by its much more membranous integument. It differs from all members of the genus in having the eyes noticeably smaller in diameter than the somewhat swollen eyestalks.

An examination of the types of *Meningodora mollis* Smith and *Notostomus fragilis* Faxon discloses no points of difference between the Atlantic and Pacific specimens.

N. mollis forms a connecting link between the primitive members of the genus belonging to the *N. vesus* group and the typical forms of the *N. robustus* group.

Seasonal Distribution: Specimens were found in every month of 1929 and 1930 in which tows were made, and the numbers taken are more or less evenly distributed over these periods. The single ovigerous female was taken in May, 1930.



Text-figure 38.

Notostomus mollis. Female taken in June, 1931, from 900 fathoms. $\times 1.64$.

Vertical Distribution: The vertical distribution is shown in the following table:

Fathoms	Males	Females	Young
500			2
600			3
700		1	13
800	2	3 (1 ovig.)	7
900		3	8
1,000		3	11

Geographical Distribution: *N. mollis* has been found off the east coast of the United States, off the coast of Brazil, in the Bay of Biscay, the Indian Ocean, north of the Philippine Islands (specimen in the U. S. National Museum) and off the west coast of Central America between Panama and the Galápagos Islands.

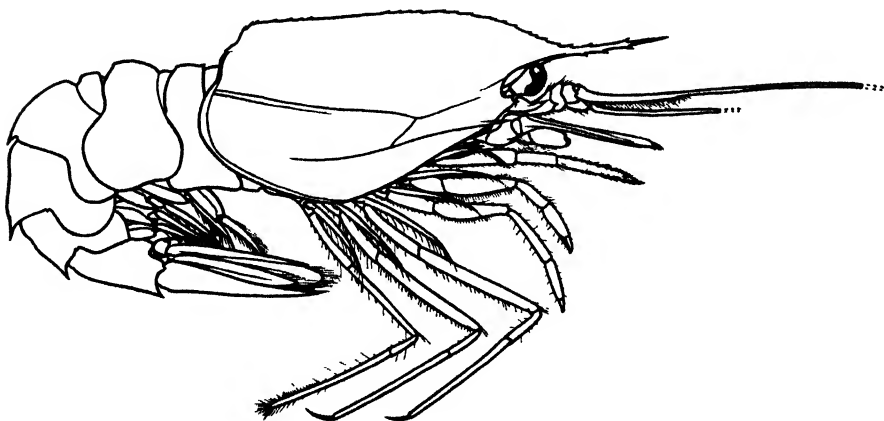
***Notostomus distirus*, sp. nov.**

Text-figs. 39 and 40.

Types: Holotype female, Cat. No. 311915, Department of Tropical Research, New York Zoological Society; Net 1281; August 9, 1931; 1,000 fathoms.

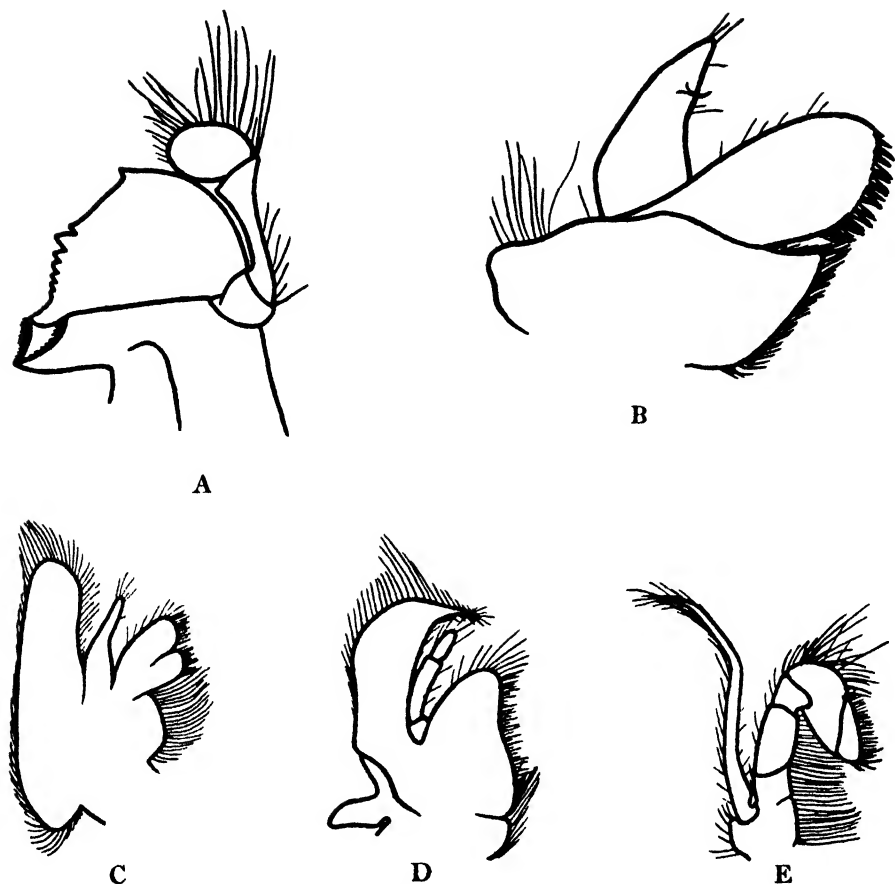
One female; Net 684; June 7, 1930; 1,000 fathoms.

Diagnosis: Integument soft. Carapace inflated, dorsal margin elevated somewhat above level of rostrum but nearly straight and denticulate for the greater part of its length. Only two prominent lateral carinae on carapace, the semi-carina below post-orbital represented by a deep sulcus and the sub-marginal carina not prominent; post-orbital and post-antennal carinae relatively close to each other and not markedly divergent behind hepatic region; post-orbital not continuous with rostral carina; no median lateral carina at base of rostrum. Rostrum with three spines on lower margin. Abdomen carinate on every somite and with a posterior tooth on third, fourth, fifth and sixth; sixth somite about one and one-third times as long as fifth. Eyes very large and black. Dactyls of first two pairs of pereopods ending in two small teeth or spines between which the fixed finger lies when the fingers are closed.



Text-figure 39.

Notostomus distirus. Holotype female. $\times 1.45$.



Text-figure 40.

Notostomus distirus. A. Mandible. B. First maxilla. C. Second maxilla. D. First maxilliped. E. Second maxilliped.

Description: Carapace moderately inflated, although not as much so as in some of the more typical members of this group. Dorsal margin sharply carinate, sparsely denticulate for its entire length, nearly straight for the greater part of its extent and somewhat, but not greatly, elevated above the level of the rostrum. Rostrum slender, reaching about as far as the tips of the antennal scales and armed on the slender portion with two dorsal and three ventral teeth. There is no median lateral carina on the rostrum. The ventral rostral carina is not continuous with the post-orbital. The latter forms an obtuse angle at the junction with the post-hepatic carina and passes backward and somewhat upward to the posterior margin. Immediately below the posterior half of this carina is a narrow longitudinal sulcus but no prominent semi-carina. The post-antennal carina rather closely approximates the post-orbital on the hepatic region and then passes backward and disappears at about the middle of the posterior branchial region. These two main carinae diverge slightly behind the hepatic region but not as much so as in *N. robustus*. The submarginal carina passing from the dorsal surface around to the hepatic region is no more prominent than in the species of other genera. Abdomen carinate on every somite, although the carina on the

first is very low. The third, fourth, fifth and sixth somites are armed with large posterior teeth. Sixth somite about one and one-third times as long as the fifth. Telson about as long as the outer branches of the uropods, deeply sulcate dorsally and armed with three pairs of minute dorso-lateral spinules and three terminal spines on either side of a median one. Eyes very large with a minute papilla on the inner side of the stalk just back of the cornea. Stylocerite reaches nearly to the end of the first segment of the antennular peduncle. Antennal scale tapering to a very bluntly angular end which reaches about as far as the outer spine. Third maxillipeds extend about as far as the antennal scales. Movable fingers of both pairs of chelipeds terminating in two inconspicuous spines which lie on either side of the fixed finger when the fingers are closed.

Color in Life: Unknown.

Measurements: Total length of holotype about 87 mm.; length of carapace 26 mm.; length of rostrum 14 mm.

The paratype is somewhat smaller, having a carapace length of about 20.5 mm.

Since there are no males or ovigerous females, there is naturally no way of determining whether these specimens are females or immature specimens.

Remarks: *N. distirus* is apparently one of the more primitive members of the *robustus* group of the genus as evidenced by the relatively slightly inflated carapace and few lateral carapacic carinae. It most closely resembles *N. murrayi* Bate, 1888, and *N. japonicus* Bate, 1888. The former was very possibly described from an immature specimen, but it apparently differs from *N. distirus* in the much greater number of teeth on the lower margin of the rostrum and the prolongation of the post-antennal carina nearly to the posterior margin of the carapace. *N. japonicus* agrees very well with the present species except that the post-orbital and post-antennal carinae are farther apart and the telson is shorter than the inner branch of the uropods.

For the possible presence of young of this species in the collection see the remarks under *N. robustus*.

***Notostomus robustus* Smith.**

Text-fig. 41

Notostomus robustus Smith, 1884, p. 377, pl. 7, fig. 2.

Notostomus beebei Boone, 1930, p. 39, fig. 6.

Notostomus robustus Chace, 1936, p. 28.

Diagnosis: Integument soft. Carapace greatly inflated, dorsal margin highly arched above level of rostrum and minutely dentate for its entire length in the adult. Four lateral carinae on posterior half of carapace including the semi-carina just below post-orbital and the submarginal carina below post-antennal; post-orbital and post-antennal carinae distinctly divergent behind hepatic region; post-orbital not continuous with rostral carina; no median lateral carina at base of rostrum. Rostrum usually with two or three spines on lower margin. Abdomen carinate on every somite and with a posterior tooth on third, fourth, fifth and sixth; sixth somite about one and one-half times as long as fifth in adult. Eyes very large and black. Dactyls of first two pairs of pereopods ending in two small, blunt, unequal teeth between which the fixed finger lies when the fingers are closed.

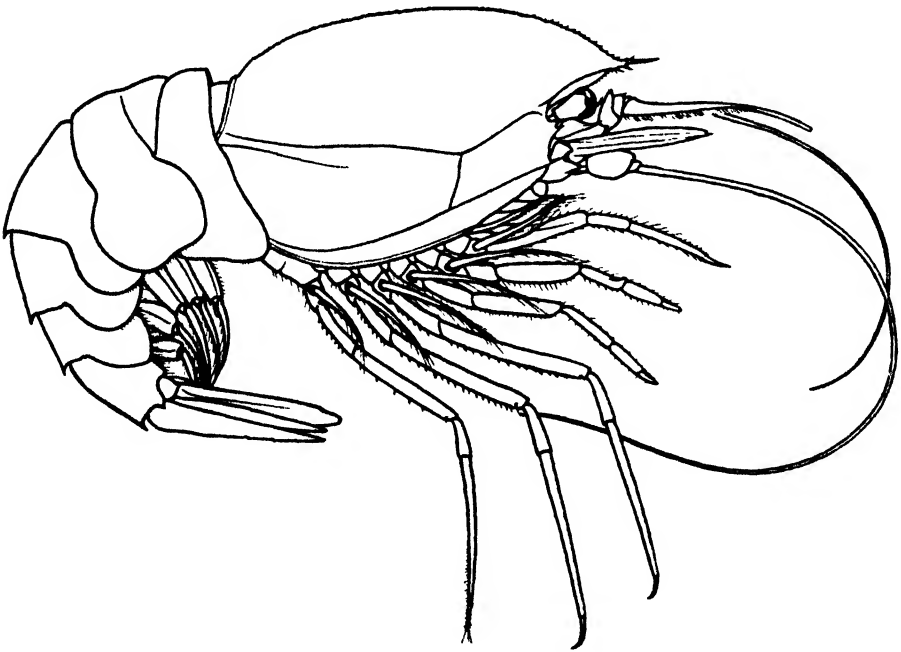
Measurements: There is no young male in the collection to determine the minimum size of adults. The only male has the carapace 49.0 mm. long. The largest female is the type of *Notostomus beebei* in which the carapace measures 45.0 mm. There are seven specimens in which the carapace is

from 19.0 to 34.0 mm. long, and the remaining 31 specimens are obviously young, the carapace measuring 3.7 to 14.8 mm.

Color in Life: Scarlet.

General Remarks: The collection contains 20 specimens which undoubtedly belong to this species; one male, one female, seven specimens which may be either females or young and eleven young. There are 20 other specimens in which the carapace is less than 7 mm. long which may belong either to *N. robustus* or to *N. distirus*. These young individuals closely resemble the adults of the *N. vescus* group in that the carapace is not greatly inflated, the dorsal carina of the carapace is not denticulate posteriorly, the lateral carinae are inconspicuous, the teeth on the third, fourth and fifth abdominal somites may be absent and the sixth abdominal somite is more than twice as long as the fifth. They can always be distinguished from the species of the *vescus* group, however, by the very large eyes.

There is little doubt in my mind that *N. beebei* Boone is a synonym of *N. robustus*. An examination of the type specimens of both species fails to disclose any differences between the two except for the presence or absence of the curious excavation in the dorsal carina at the base of the rostrum. If this character was found in but a single specimen one would readily assume that it was caused by an injury but, curiously enough, the female cotype of *N. robustus* has almost exactly the same kind of excavation armed anteriorly with a "quadrispine." Smith failed to mention this abnormality in his description and apparently assumed that it was the result of an injury. Since only four positively adult specimens of this species are known, two males and two females, and since both females have this curious depression in the dorsal carina, the possibility that this is a sexual character cannot be entirely disregarded.



Text-figure 41.

Notostomus robustus. Young female taken in August, 1930, from 800 fathoms. $\times 1.32$.

Seasonal Distribution: The adult male was taken June 19, 1929, and the type female of *N. beebei* on May 25, 1929. Other specimens with a carapace length exceeding 19 mm. were taken in June and July, 1929, and in August and September, 1930. Specimens with a carapace length of 7 to 15 mm. were found in June, July and September, 1929, and in May and September, 1930.

Vertical Distribution: The adult male was taken in 1,000 fathoms and the adult female in 900. Of the intermediate group in which the carapace measures from 19 to 34 mm., three were found at 800, one at 900 and two at 1,000 fathoms. Of the smallest specimens with a carapace length of 7 to 15 mm., one was taken in 600 fathoms, three in 700, one in 800, four in 900 and one in 1,000.

Geographical Distribution: *N. robustus* is known only from the western North Atlantic between 42° north latitude and Bermuda.

***Notostomus perlatus* Bate ?**

Text-fig. 42.

? *Notostomus perlatus* Bate, 1888, p. 831, pl. 134, fig. 2.

? *Notostomus brevirostris* Bate, 1888, p. 832, pl. 134, fig. 3.

? *Notostomus perlatus* Balss, 1925, p. 268.

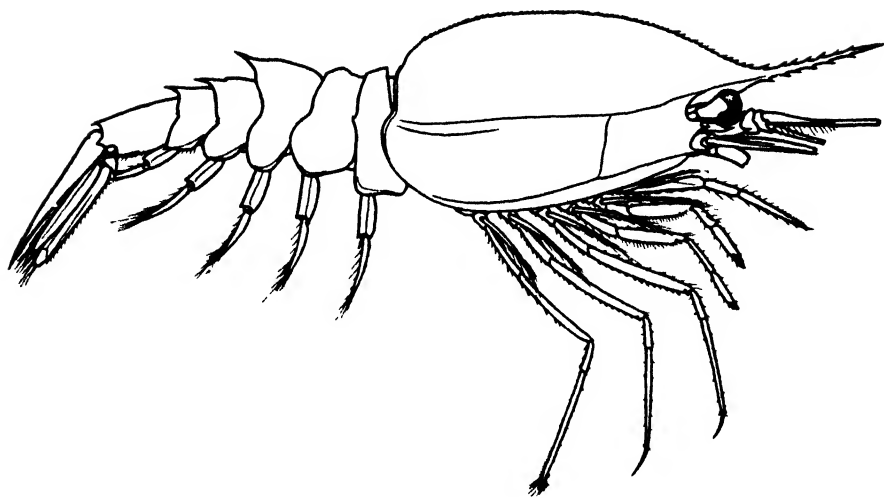
Diagnosis: Integument soft. Carapace greatly inflated, dorsal margin highly arched above level of rostrum and minutely dentate for its entire length. Four lateral carinae on posterior half of carapace, including the semi-carina just below the post-orbital and the submarginal carina below the post-antennal; post-orbital and post-antennal carinae not markedly divergent behind hepatic region; post-orbital continuous with rostral carina; no median lateral carina at base of rostrum. Rostrum with six teeth on lower margin. Abdomen carinate on every somite and with a posterior tooth on third, fourth, fifth and sixth; sixth somite about and one three-fourths times as long as fifth. Eyes very large and black. Dactyls of first two pairs of pereopods ending in two small unequal teeth between which the fixed finger lies when the fingers are closed.

Color in Life: Unknown.

Remarks: A single young specimen (carapace length 14.6 mm.) from Net 999; June 5, 1931; 700 fathoms, is tentatively assigned to this species.

The only apparent difference between this specimen and *N. perlatus* lies in the length of the rostrum. There are two adult male specimens (carapace lengths 51 and 52 mm.) in the U. S. National Museum which were taken by the *Albatross* in the Gulf of Mexico southeast of the Mississippi delta which almost certainly belong to the same species as this young Bermuda specimen. These two specimens differ from all other known specimens of *N. perlatus* in having the rostrum reaching as far as the ends of the antennal scales rather than no more than half that distance. Since the rostrum is usually longer in immature specimens in this genus, its greater length in the Bermuda example is by no means unexpected. Since these three specimens agree with *N. perlatus* in all other particulars, it does not seem desirable at present to separate them merely on the basis of the rostral length.

Another possibility is that this form is really *N. gibbosus* A. Milne Edwards, 1881, which was taken by the *Blake* off Grenada. It corresponds reasonably well with the figure of that species (A. Milne Edwards, 1883) except for the absence of a semi-carina below the posterior portion of the post-orbital carina. Another discrepancy is the fact that Milne Edwards describes the telson as being distinctly shorter than the outer branch of the uropods. The type of *N. gibbosus* cannot be found in the Museum of Com-



Text-figure 42.

Notostomus perlatus ?. Young taken in June, 1931, from 700 fathoms. $\times 2.56$.

parative Zoology. It is to be hoped that it is in the Paris Museum, for it is only by examination of this type specimen that the correct status of the species can be determined.

Geographical Distribution: All of the recorded specimens of *N. perlatus* have been taken within ten degrees of the equator; off the coast of Brazil, off the west coast of Africa, off the east coast of Africa, in the Indian Ocean and south of the Philippines. I have also seen a typical specimen of *N. perlatus* in the U. S. National Museum which was taken east of the Marquesas Islands, also within ten degrees of the equator. The only records from outside of this equatorial belt in addition to the present specimen are the two males, mentioned above, from the Gulf of Mexico.

***Notostomus westergreni* Faxon ?**

Text-fig. 43.

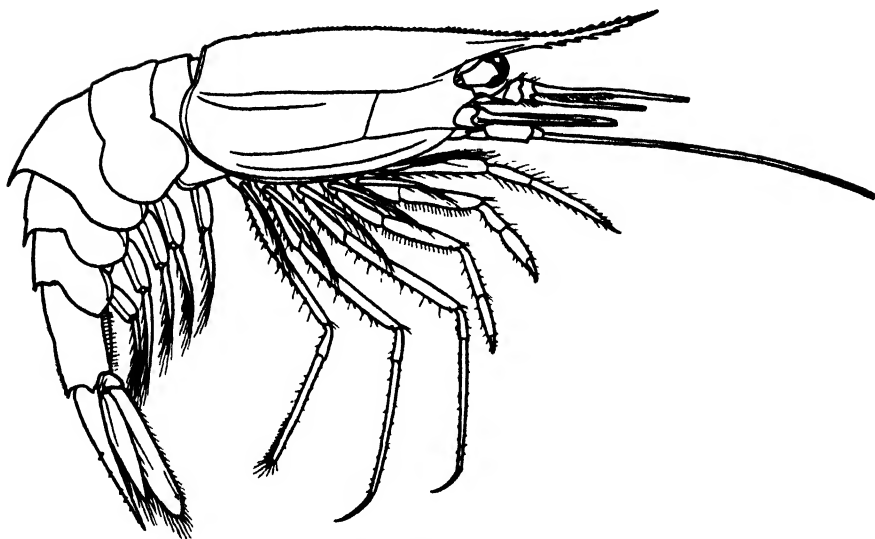
? *Notostomus westergreni* Faxon, 1893, p. 208; 1895, p. 171, pl. F.

? *Notostomus westergreni* Balss, 1925, p. 269.

Diagnosis: Integument soft. Carapace moderately inflated, dorsal margin arched but slightly above level of rostrum and denticulate for its entire length. Five lateral carinae on posterior half of carapace, including the semi-carina just below post-orbital and the submarginal carina along lower edge; post-orbital and post-antennal carinae nearly parallel; post-orbital not continuous with rostral carina; a median lateral carina at base of rostrum. Rostrum with eight or nine teeth on lower margin. Abdomen carinate on every somite and with a posterior tooth on third, fourth, fifth and sixth; sixth somite nearly twice as long as fifth in the young. Eyes very large and black. Dactyls of first two pairs of pereopods ending in two small spines between which the fixed finger lies when the fingers are closed.

Color in Life: The type specimen of *N. westergreni* was bright red. No color notes were taken on the Bermuda specimens.

Remarks: Two immature specimens are referred to *N. westergreni*



Text-figure 43.

Notostomus westergreni ?. Young taken in July or August, 1929, from 900 fathoms. $\times 3.70$.

with some hesitation. One specimen, with a carapace length of 9.0 mm., was taken in Net 325, 330, 362 or 382; July 24 to August 16, 1929; 900 fathoms. The other, with a carapace length of 7.8 mm., is from Net 613 or 614; May 21, 1930; 600 fathoms.

These specimens differ from the male type of *N. westergreni* as follows; the dorsal margin of the carapace is less elevated, there are fewer teeth on the lower margin of the rostrum and the sixth abdominal somite is proportionately longer. All of these characters might well be attributed to the obvious immaturity of the specimens. Although Faxon described this species as having a posterior tooth on the "third, fourth and fifth" somites of the abdomen, the type has a well developed tooth on the sixth somite as well, as shown in Faxon's figure. I have also seen a specimen in the U. S. National Museum in which the carapace is 12.5 mm. long, which corresponds in every particular with these Bermuda specimens except that the semi-carina fuses anteriorly with the post-orbital. This specimen was taken by the *Albatross* off the coast of Peru not far from the type locality of *N. westergreni*.

It is obviously impossible at present to determine with certainty young specimens of *Notostomus* due to the comparative scarcity of material, but of the three known species of the genus which have five lateral carinae on the posterior half of the carapace, *N. westergreni*, *N. patentissimus* Bate, 1888, and *N. longirostris* Bate, 1888, the present specimens are much nearer the first than to the other two.

Geographical Distribution: There are but three recorded specimens of *N. westergreni*; the type from off the coast of Ecuador, a specimen from near the Keeling Islands in the Indian Ocean and the third from off Cape Point, South Africa.

Genus *Ephyrina* Smith, 1885.

Carapace with a blunt ridge running along the median lateral line from the orbital region to the hind margin, and with an oblique ridge delimiting the hind margin of the hepatic furrow. Abdomen smoothly rounded, not

carinate, throughout its length. Telson more or less truncate, not terminating in a sharply pointed end-piece laterally armed with spines. Ischial and meral joints of the pereopods abnormally broad and flattened. Exopods of third maxillipeds and pereopods neither foliaceous nor rigid. Eyes well pigmented. Outer margin of antennal scale not armed with a series of spines. Incisor process of mandible toothed for only half the length of the cutting edge.

KEY TO THE KNOWN SPECIES OF *Ephyrina*.

1. A posterior tooth or spine on third abdominal somite
No posterior tooth or spine on third abdominal somite; ten to thirteen pairs of lateral spines on telson *E. hoskynii*.
2. Posterior tooth on third abdominal somite triangular; twenty to twenty-five pairs of lateral spines on telson *E. benedicti*
Posterior tooth on third abdominal somite broad and bifid at the end; five to eight pairs of lateral spines on telson *E. bifida*.

***Ephyrina hoskynii* Wood-Mason.**

Text-fig. 44.

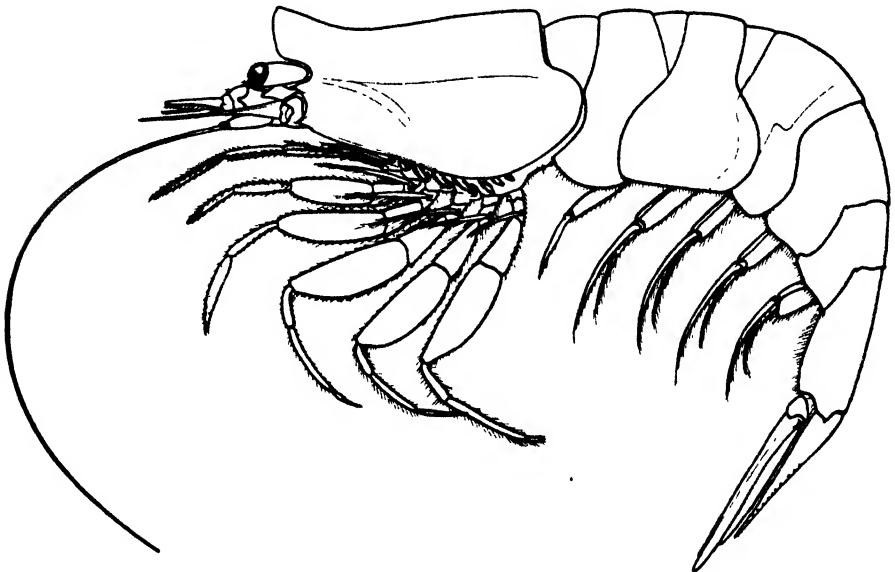
Ephyrina hoskynii Wood-Mason & Alcock, 1891, p. 194.

Ephyrina hoskynii Kemp, 1910, p. 68, pl. 7, figs. 1-6.

Ephyrina benedicti Chace, 1936, p. 29 (part).

Diagnosis: Abdomen without dorsal teeth or spines on any somite; telson armed with ten to thirteen pairs of lateral spinules. Eyes not broader than eyestalks.

Color in Life: Dark red, according to Alcock, 1901. No color notes were taken on the Bermuda specimen.



Text-figure 44.

Ephyrina hoskynii. Female (after Kemp, 1910). $\times 1.19$.

Remarks: This species is represented by a single young specimen having a carapace length of 6.8 mm. taken in Net 896; September 16, 1930; 700 fathoms.

The large number of specimens of various sizes with bifid spines on the third abdominal somite in the present collection have forced me to the conclusion that there are in reality three known species of *Ephyrina* rather than one variable one. There appears to be no difficulty in separating these forms since they differ, not only as regards the teeth on the third and fourth abdominal somites, but also in the number of lateral telson spines and the size of the cornea of the eye. There is probably little in the form of the rostrum that is of taxonomic importance since all of the described forms may be found among the various age groups of a single species.

Geographical Distribution: *E. hoskynii* is known from off the southwest coast of Ireland, the Bay of Biscay, off the coast of Spain or Portugal, the Arabian Sea in the vicinity of the Laccadive Islands and the Bay off Bengal off Ceylon.

***Ephyrina bifida* Stephensen.**

Text-fig. 45.

Ephyrina bifida Stephensen, 1923, p. 58, fig. 18.

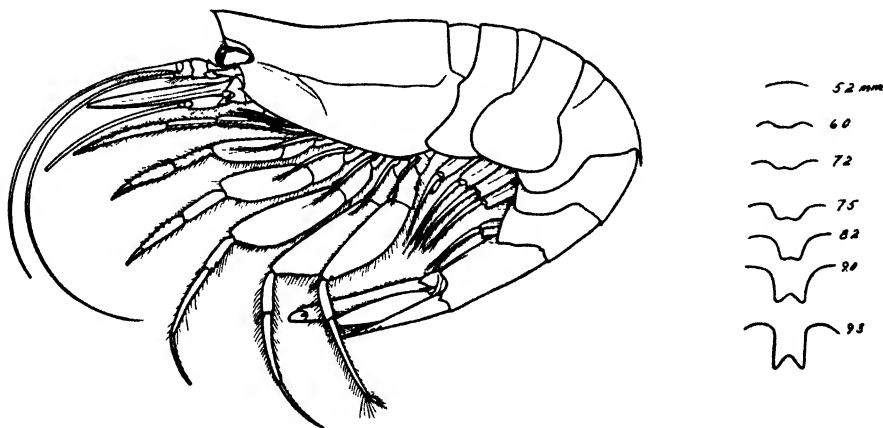
Ephyrina benedicti Balss, 1925, p. 269, figs. 38 and 39.

Ephyrina benedicti Chace, 1936, p. 29 (part).

Diagnosis: Abdomen with a broad, bifid tooth on third somite and a small triangular tooth on fourth somite in the adult; telson armed with five to eight pairs of lateral spinules. Eyes distinctly broader than eyestalks.

Measurements: The collection contains no adult male or ovigerous female specimens by which the size of adults might be gauged. The largest specimen, apparently a female, has a carapace length of 21.3 mm. In the smallest specimen the carapace measures 3.9 mm., but in this specimen, as in several others slightly larger, the telson still retains its larval form.

Color in Life: Unknown.



Text-figure 45.

Ephyrina bifida. Female taken in September, 1931, from 1,000 fathoms. $\times 1.19$. On the right is shown the development of the tooth on the third abdominal somite in this species with the carapace lengths in mm.

General Remarks: The collection contains 70 specimens, five of which have a carapace length exceeding 15 mm. and are tentatively designated as females.

In specimens of *E. bifida* having a carapace length of 5 mm. or less there are no teeth on any of the abdominal somites. At about 6 mm. the tooth on the third somite is represented by a broad, shallow lobe which becomes faintly notched at about 7 mm. From this stage on, the tooth gradually increases in length and becomes more distinctly bifid, the mature condition being reached in specimens having a carapace length of about 9 mm. The small tooth on the fourth somite first appears in specimens having a carapace length of 8 or 9 mm. Young specimens lacking either of these spines may be distinguished from those of *E. hoskynii* by the smaller number of lateral spines on the telson.

One young specimen of this species was found in the stomach of the fish, *Gonostoma elongatum*.

Seasonal Distribution: Specimens were taken in every month of 1929 and 1930 in which towing was done, with the largest numbers appearing in September of each year. Specimens of various sizes were scattered at random over these months and individuals having carapace lengths between 4 and 5 mm. were taken in every month.

Vertical Distribution: This species was taken in depths ranging from 400 to 1,000 fathoms, but only one specimen was found above 600 fathoms and no specimens having a carapace length greater than 5.5 mm. were taken in less than 800 fathoms. The largest number of specimens were found at 800 fathoms, but in none of these did the carapace exceed 10 mm. in length; only at 900 and 1,000 fathoms were possibly adult specimens collected.

Geographical Distribution: Only four specimens of this species have been recorded previously. These came from the Bay of Biscay, the Gulf of Guinea off the west coast of Africa, the Indian Ocean east of the Maldive Islands and the southern Indian Ocean west of Australia.

Genus *Hymenodora* G.O. Sars, 1877.

Carapace with no ridge or carina running the entire length of the median lateral line from the orbital region to the hind margin, and without an oblique ridge or carina delimiting the hind margin of the hepatic furrow. Abdomen smoothly rounded throughout, without a dorsal carina on any somite. Telson truncate at the tip, not terminating in a sharply pointed end-piece laterally armed with spines. Pereiopods slender. Exopods of third maxillipeds and pereiopods neither foliaceous nor rigid. Eyes small and very slightly pigmented. Outer margin of antennal scale not armed with a series of spines. Incisor process of mandible toothed for the entire length of its cutting edge.

Only one species is known from the Bermuda area.

Hymenodora gracilis Smith.

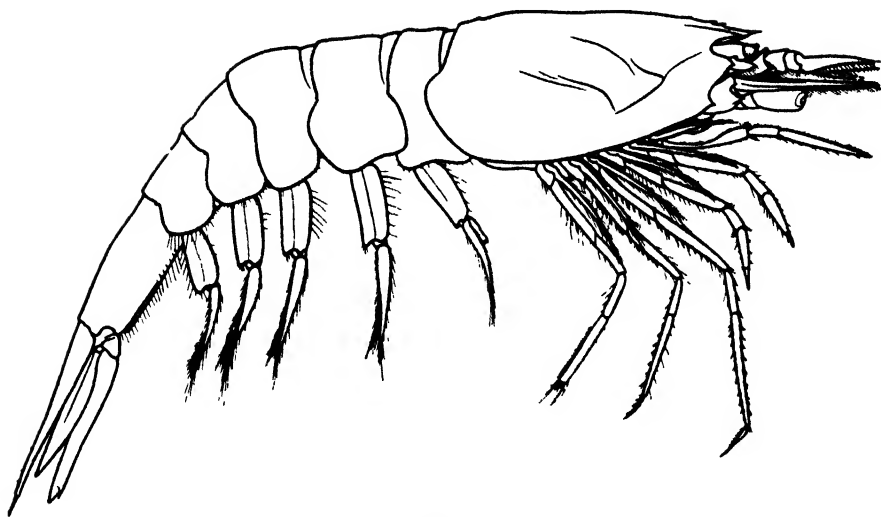
Text-figs. 46-49.

Hymenodora gracilis Smith, 1886, p. 681, pl. 12, fig. 6.

Hymenodora gracilis Stephensen, 1923, p. 60.

Hymenodora glacialis Chace, 1936, p. 29 (part).

Diagnosis: Integument extremely soft and fragile, rostrum reaching about as far as tips of eyes, a groove passing upward and backward from



Text-figure 46.

Hymenodora gracilis. Male taken in August or September, 1931, from 900 fathoms. $\times 2.66$.

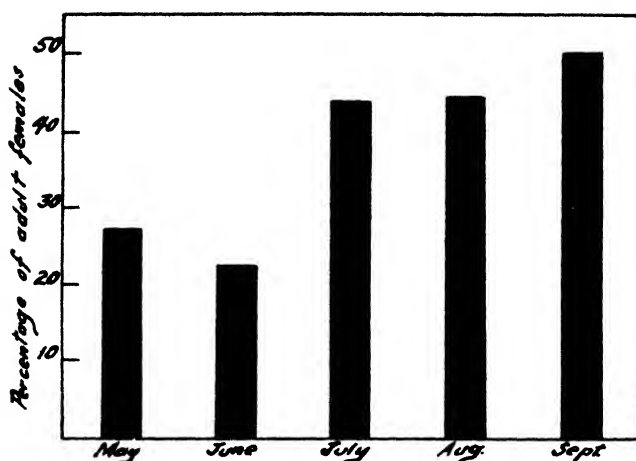
the middle of the hepatic furrow but no similar groove converging toward the first from the supra-branchial groove, end of squamous portion of antennal scale truncate and not reaching beyond base of outer spine.

Measurements: The smallest recognizable males have a carapace length of 9.0 mm. The largest males have the carapace about 13.0 mm. long. The smallest ovigerous females are about the same size as the smallest males or even slightly smaller. The male appears to attain a somewhat larger size than the female in this species; if, as seems likely, the females mature at a smaller size than the males there is no way of distinguishing these small, non-ovigerous females from immature specimens. The smallest specimens seen have a carapace length of 3.0 mm. Since specimens of this species are usually in poor condition due to the extremely fragile integument, it is often difficult to obtain accurate measurements. The eggs are very large in comparison with the size of the animal, measuring 2.3 by 2.0 mm.

Color in Life: Two slightly different shades of color were noted in Bermuda specimens of this species. In two ovigerous females taken in Net 1099 the body and appendages were bright scarlet with a faintly yellowish tinge to the tips of the appendages and to the setae. The eyes were buffish, with the facets outlined in brownish-black. The eggs were pansy-purple with the developing embryo pale peach-colored. In another ovigerous specimen taken in Net 1106 the body and appendages were grenadine red with the scarlet red heart showing through the dorsal part of the carapace. The eyes were as in the above specimens. The eggs, which were not well-developed in this specimen, were spectrum red.

General Remarks: The collection contains 1,829 specimens; 73 males, 206 females, of which 78 are ovigerous, and 1,550 young.

Dr. Stanley Kemp has convinced me that *H. gracilis* is distinct from *H. glacialis* with which it has often been confused. I believe that Dr. Kemp will clarify the differences in a forthcoming paper; the diagnosis given above is sufficient to recognize the species, the only one I have seen from the Bermuda area. The only additional point of taxonomic interest is the fact



Text-figure 47.

Seasonal distribution of ovigerous females of *Hymenodora gracilis* computed from specimens taken in 1929 and 1930.

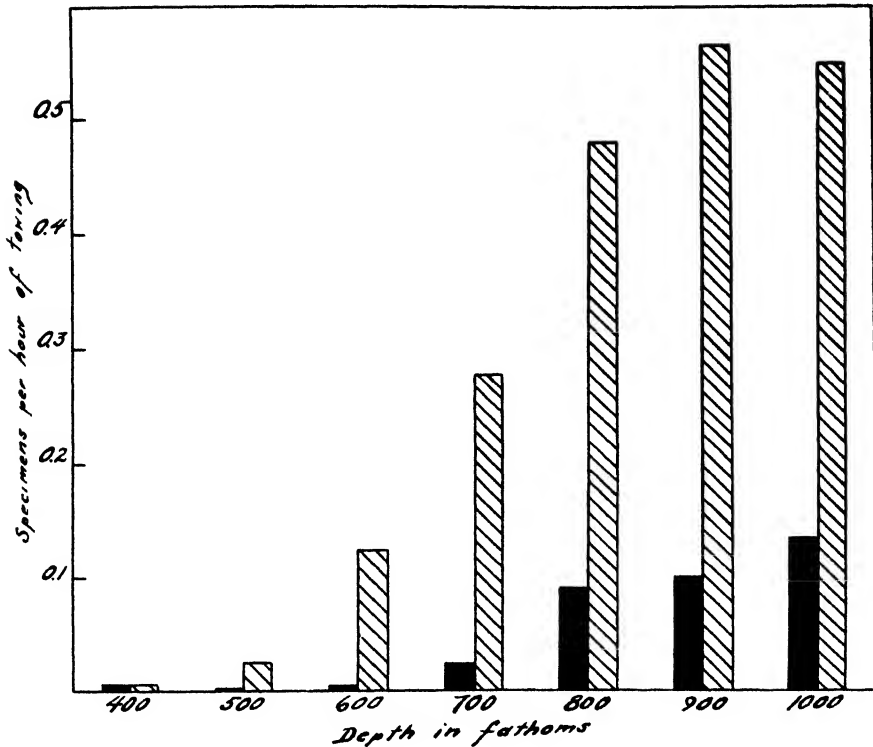
that a few of the specimens have five or six terminal spines on the telson instead of the usual four.

Seasonal Distribution: There is no apparent monthly fluctuation in the numbers of either adults or young taken during that part of the year in which towing was carried on. Naturally, there were proportionately more young taken in those months in which a large part of the tows were made above 900 or 1,000 fathoms and conversely, a greater percentage of adults were taken during the months when more of the deeper tows were made, but when all of these factors are taken into consideration there are no striking disclosures regarding the seasonal distribution of the population of *H. gracilis*. In contrast to the results obtained with *Acanthephyra purpurea*, however, there appears to be an increase in the numbers of ovigerous females during the latter part of the summer as shown in Text-fig. 47. Although these results may be entirely due to chance, it is difficult to suppose that the percentage error would be great enough to account for the fact that out of forty females taken in June only nine were ovigerous, whereas out of forty-two females in September twenty-one were carrying eggs.

Vertical Distribution: The vertical distribution of the entire catch of *H. gracilis* is shown in the following table:

Fathoms	Males	Females	Young
400.....		1	1
500.....	1		17
600.....	1	1	83
700.....	1	14 (5 ovig.)	193
800.....	10	51 (21 ovig.)	334
900.....	15	59 (24 ovig.)	417
1,000.....	45	78 (28 ovig.)	503
1,100.....		1	2
1,200.....		1	

The distribution of the adult and young when reduced to the number of specimens taken in an average hour of towing at each depth is shown in Text-fig. 48. All of these specimens were taken in the daytime. This distribution naturally suggests that a large part of the adult portion of the popula-

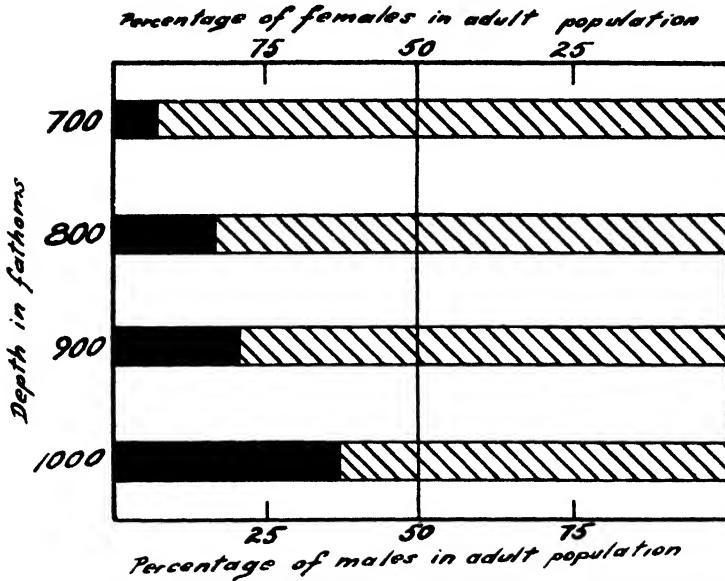


Text-figure 48.

Vertical distribution of adults (solid bars) and young (hatched bars) of *Hymenodora gracilis*.

tion is usually found at depths exceeding 1,000 fathoms. That they were not taken in greater numbers at 1,100 and 1,200 fathoms may be due to the fact that these depths are too near the bottom in the area investigated. It is not unlikely that additional towing at greater depths in this general region might reveal a much greater proportion of adults. An increase in the proportionate number of males as the depth becomes greater, similar to the vertical distribution of the sexes in *Acantheephyra purpurea*, is apparent in this species as shown in Text-fig. 49. Since the females are more numerous at every haul, it is probable that this sex is normally more abundant than the males in this species, but one cannot entirely ignore the possibility that if the increase in the male component of the population continues with increase in depth to 2,000 fathoms or over this sex ratio might be more nearly equalized; if, in the case of *Acantheephyra purpurea*, only specimens from 600 fathoms and above had been seen, one would assume that the females were distinctly in the majority, but when the deeper hauls are considered just the reverse proves to be true. It will be noticed from the table that the ovigerous females were fairly well scattered from 700 to 1,000 fathoms, varying from 35 to 42 per cent. of the adult females at those levels.

Geographical Distribution: Since *H. gracilis* has so frequently been confused with *H. glacialis*, its distribution is very imperfectly known. All of the specimens which I have seen from the temperate North Atlantic, with the exception of a single specimen taken southeast of Georges Bank, appear



Text-figure 49.

Relative abundance of males and females of *Hymenodora gracilis* from 700 to 1,000 fathoms. Solid bars represent the male fraction of the adult population; hatched bars the female.

to belong to *H. gracilis*; possibly *H. glacialis* is usually confined to the arctic and subarctic regions in the North Atlantic. However, the specimens from the Gulf of Panama referred to this species by Faxon (1895, p. 168) prove to be typical specimens of *H. glacialis*.

Genus *Systellaspis* Bate, 1888.

Carapace without a straight ridge or carina running along the median lateral line from the orbit to the hind margin, and without an oblique ridge or carina delimiting the hind margin of the hepatic furrow. Abdomen never dorsally carinate on the sixth somite. Telson not truncate at the tip but terminating in a sharply pointed end-piece laterally armed with spines. Pereiopods not abnormally broad and flattened. Exopods of third maxillipeds and pereiopods neither foliaceous nor rigid. Eyes well pigmented and usually large. Outer margin of antennal scale not armed with a series of spines. Incisor process of mandible toothed for the entire length of its cutting edge.

KEY TO THE BERMUDIAN SPECIES OF *Systellaspis*.

- Rostrum triangular and less than half as long as carapace; hind margins of fourth and fifth abdominal somites not denticulate; sixth somite at least twice as long as fifth *S. braueri*.
- Rostrum slender and longer than carapace; hind margins of fourth and fifth abdominal somites denticulate; sixth somite less than twice as long as fifth *S. debilis*.

***Systellaspis braueri* (Balss).**

Text-fig. 50.

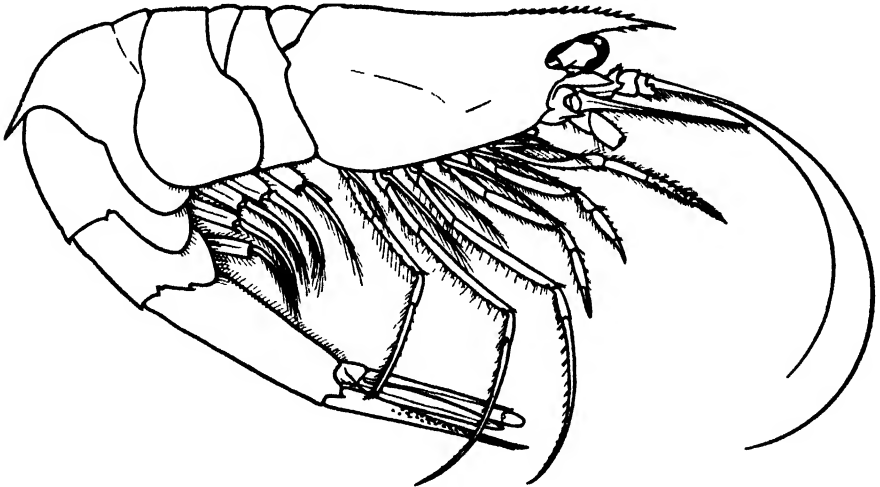
? *Systellaspis echinurus* Coutière, 1911, p. 158.*Acanthephyra braueri* Balss, 1914, p. 594.*Systellaspis densispina* Stephensen, 1923, p. 57, fig. 17.*Systellaspis braueri* Balss, 1925, p. 245, text-figs. 17-20, pl. 21.

Diagnosis: Rostrum triangular and less than half as long as carapace. No sharp dorsal carina on any abdominal somite; hind margins of fourth and fifth somites not denticulate; a blunt lobe on anterior margin of first abdominal somite overlapping carapace; a deep notch in hind margin of fifth pleuron; sixth somite at least twice as long as fifth.

Color in Life: Unknown.

Remarks: The collection contains thirteen specimens of this species, ranging in size from 4.2 to 14.3 mm. in carapace length. All but two of these specimens are obviously young. The two largest specimens, possibly mature females, were taken in June and September, 1929, and the others were scattered from May to September of 1929, 1930 and 1931. The depths in which they were found varied from 700 to 1,000 fathoms, only the smaller specimens being taken in the shallower depths and the two largest in 1,000 fathoms.

As Stephensen has pointed out, it is very likely that *S. echinurus* Coutière belongs to this species, but the description is much too inadequate to permit recognition of the earlier name. Balss is probably correct in combining *S. densispina* Stephensen with this species.



Text-figure 50.

Systellaspis braueri. Female taken in September, 1929, from 1,000 fathoms. $\times 2.13$.

Geographical Distribution: Only five or six specimens of *S. braueri* have been recorded heretofore. They were found in the Bay of Biscay, in the Gulf of Guinea off the west coast of Africa and in the Bay of Bengal off Ceylon. There is one additional specimen in the U. S. National Museum which was taken by the *Albatross* off Los Angeles, California, and a large female has recently been acquired by the Museum of Comparative Zoology from southeast of Georges Bank.

***Systellaspis debilis* (A. Milne Edwards).**

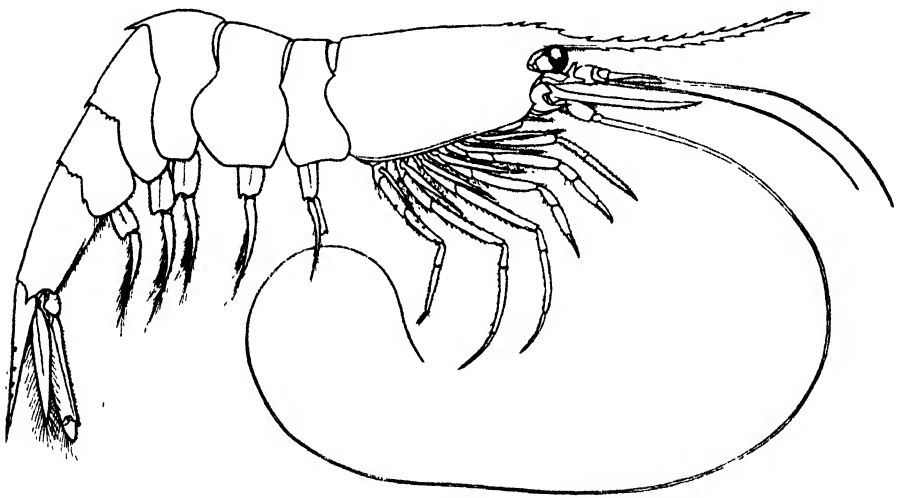
Text-figs. 51-53.

Acantheephyra debilis A. Milne Edwards, 1881a, p. 13.*Miersia gracilis* Smith, 1882, p. 70, pl. 11, figs. 4-4d.*Acantheephyra debilis* var. *Europoea* A. Milne Edwards, 1883.*Acantheephyra gracilis* Smith, 1886, p. 672.*Systellaspis debilis* Coutière, 1905, p. 5, fig. 2.*Systellaspis bouvieri* Coutière, 1905, p. 8, fig. 3.*Systellaspis debilis* var. *indica* de Man, 1920, p. 51, pl. 6, figs. 11-11f.*Systellaspis debilis* Balss, 1925, p. 242.

Diagnosis: Rostrum slender and usually longer than carapace. Abdomen dorsally carinate on most of third and posterior portion of fourth somites; hind margins of fourth and fifth somites denticulate either side of median spine; an acute lobe on anterior margin of first abdominal somite overlapping carapace; a notch in hind margin of fifth pleuron, sixth somite less than twice as long as fifth.

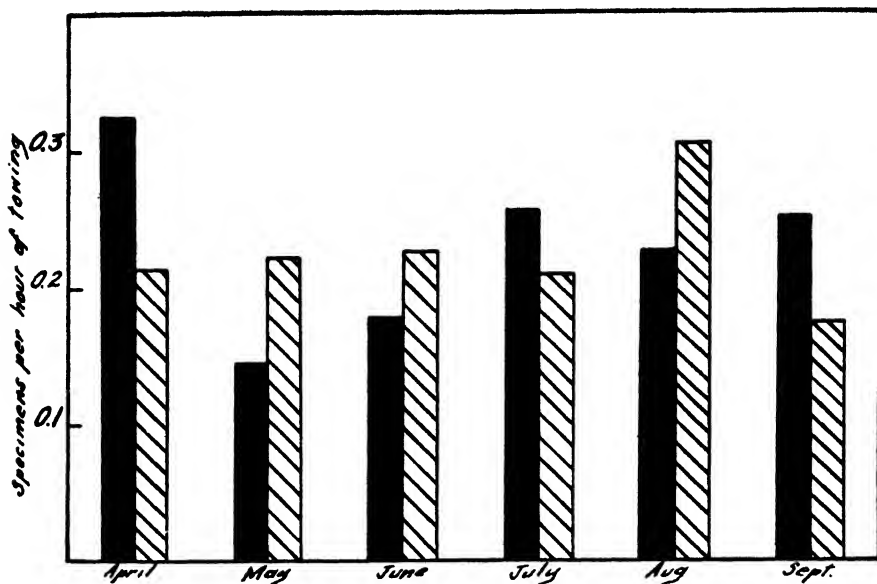
Measurements: The smallest recognizable males show some slight variation in size, having a carapace length of from 7.2 to 7.8 mm. The largest males have a carapace length of about 14.0 mm. and the largest females about 14.2 mm. The smallest ovigerous females examined had a carapace length of 10.9 mm. The youngest specimens have the carapace 2.8 mm. long. The eggs vary somewhat in size depending on their degree of development and state of preservation, but their average measurements are about 3.7 by 1.9 mm.

Color in Life: The largest adult specimens have the entire body and appendages, except for the eyes and light organs, scarlet-red, with the antennal scales, antennae, pleopods and uropods tinged with salmon-orange. The eyes are dark brown; the light organs have deep bluish-purple centers and dark red reflectors.. The eggs are spectrum red. In somewhat smaller individuals the body color varies from scarlet-red to white spotted with



Text-figure 51.

Systellaspis debilis. Male taken in June, 1929, from 600 fathoms. $\times 2.12$.



Text-figure 52.

Seasonal distribution of adults (solid bars) and young (hatched bars) of *Systellaspis debilis* computed from specimens taken in 1929 and 1930.

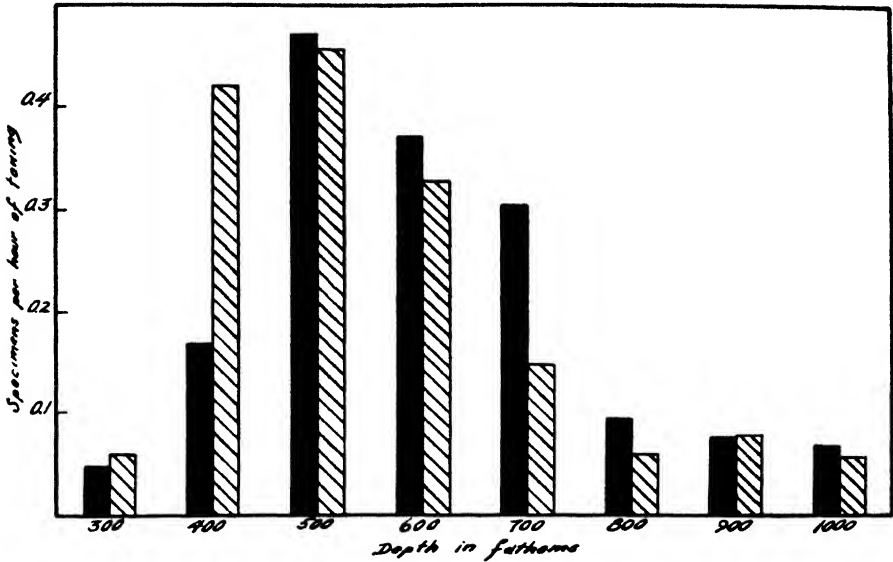
scarlet, the abdomen frequently showing considerable white in young specimens; in those specimens which are not of maximum size the tips of the antennae, rostrum, pleopods, uropods and telson are nearly white.

General Remarks: The collection contains 1,949 specimens of this species; 470 males, 567 females, of which 327 are ovigerous, and 912 young. Of the ovigerous specimens, 66 carry eggs in which the eyes are visible.

S. debilis can be distinguished from all other members of the genus by the denticulate hind margins of the terga of the fourth and fifth abdominal somites.

Luminescence: The position of the photophores in *S. debilis* is given by Kemp, 1919 (p. 64). Harvey, 1931, discusses the chemistry of the luminescence in this form and also reports that specimens can be stimulated to emit "a cloud of bluish luminescent secretion . . . from glands near the mouth." Observations on the luminescence of living specimens will be found on page 204 of the present paper.

Seasonal Distribution: The monthly distribution of the adults and young of this species in 1929 and 1930 is shown in Text-fig. 52. Obviously, the fluctuation in the population does not appear to follow any definite plan. Curiously enough, the young population seems to remain more stable than the adult. The seasonal distribution of ovigerous females similarly discloses little of significance; in each month of 1929 and 1930 in which towing was done, with the exception of April, more than half of the females were carrying eggs and more than six per cent. of the female population carried eggs in which the eyes are visible. When one examines the yearly hauls for 1929, 1930 and 1931, it is found that in 1929 the yield of this species per hour of towing was 0.249 adults and 0.224 young, whereas in 1930 and 1931 this figure was 0.190 for the adults in each year and 0.200 and 0.114 respectively for the young. However, it is found that the numbers of ovigerous females per hour of towing in 1929 and 1930 were nearly the same, 0.075 and 0.073



Text-figure 53.

Vertical distribution of adults (solid bars) and young (hatched bars) of *Systellaspis debilis*.

respectively. Of course, this also reveals a dissimilarity in the proportion of adult females which were ovigerous in the two years; in 1929 only 58.2 per cent. were ovigerous, while in 1930 75.5 per cent. were carrying eggs, and these proportions remain fairly uniform when these years are analyzed month by month. It is evident from an examination of the collection that practically all of the females in which the carapace is more than about 11.5 mm. long were ovigerous, so the explanation of the smaller proportion of ovigerous specimens in 1929 must be that young females with a carapace length of from 7.5 to 11.5 mm. were more abundant in that year than in 1930. On the other hand, although adult specimens seemed to be just as abundant in 1931 as in 1930, only 0.048 ovigerous females were taken per hour of towing and only 43.6 per cent. of the adult females were carrying eggs. Since towing in 1931 was carried on from July to October, while in 1930 it was done from May to September, it is somewhat hazardous to compare these two years in this manner. However, it would appear that young females were even more abundant in 1931 than in 1929.

Vertical Distribution: The vertical distribution of the total catch is as follows:

Fathoms	Males	Females	Young
100			1
200			
300	2	9 (3 ovig.)	14
400	13	23 (3 ovig.)	90
500	153	186 (102 ovig.)	329
600	127	125 (73 ovig.)	222
700	92	120 (80 ovig.)	103
800	34	32 (21 ovig.)	41
900	28	29 (20 ovig.)	59
1,000	21	42 (24 ovig.)	52
1,100			
1,200			1

The relation of these specimens to the number of hours of towing is shown in Text-fig. 53. All of these specimens were taken in the daytime. Apparently the center of distribution of this species is at 500 or 600 fathoms for the adults and 400 fathoms or above for the young. The rapid thinning out of the population of *S. debilis* above 500 fathoms and the fact that a single young specimen was found at 100 fathoms tend to support observations made in the bathysphere by Beebe (1934, pp. 303 and 340) that specimens are present in the upper levels, but that they may be able to avoid the nets in this better lighted zone. From night hauls made by *Atlantis* in this general area, it is known that *S. debilis* can be taken at levels at least as shallow as 220 fathoms during the hours of darkness (Welsh, Chace & Nunnemacher, 1937, p. 190). It will be seen from the table that at every depth at which significant numbers of this species were taken more than half of the adult females were ovigerous. Likewise, there was no strikingly large proportion of those carrying eyed eggs at any particular level. There is no evidence in this species that males are proportionately more abundant at deeper levels as was noted in *Acanthephyra purpurea*; in fact, the greatest proportion of females was found at 1,000 fathoms.

Geographical Distribution: *S. debilis* appears to be most abundant in the North Atlantic, but it has been recorded as well from the eastern South Atlantic, the Indian Ocean, the Malay Archipelago and the Hawaiian Islands.

Genus **Oplophorus** H. Milne Edwards, 1837.

Carapace without a straight ridge or carina running along the median lateral line, and without an oblique ridge or carina delimiting the hind margin of the hepatic furrow. Abdomen armed with remarkably long spines on either the second, third and fourth or the third, fourth and fifth somites; it is usually carinate on those somites provided with spines and not on the others. Telson terminating in a sharp point which may or may not be armed with lateral spines. Pereiopods short and slender. Exopods of third maxillipeds and pereiopods foliaceous and usually rigid. Eyes large and well pigmented. Outer margin of antennal scale usually armed with a series of spines. Incisor process of mandible toothed for the entire length of its cutting edge.

KEY TO THE BERMUDIAN BATHYPELAGIC SPECIES OF *Oplophorus*.

Abdomen armed with long spines on second, third and fourth somites

O. spinicauda.

Abdomen armed with long spines on third, fourth and fifth somites

O. grimaldii.

Oplophorus spinicauda A. Milne Edwards.

Text-fig. 54.

Oplophorus spinicauda A. Milne Edwards, 1883.

Oplophorus foliaceus Rathbun, 1906, p. 922, pl. 20, fig. 8.

Hoplophorus foliaceus Balss, 1925, p. 249.

Acanthephyra anomala Boone, 1927, p. 104, fig. 21 (holotype only).

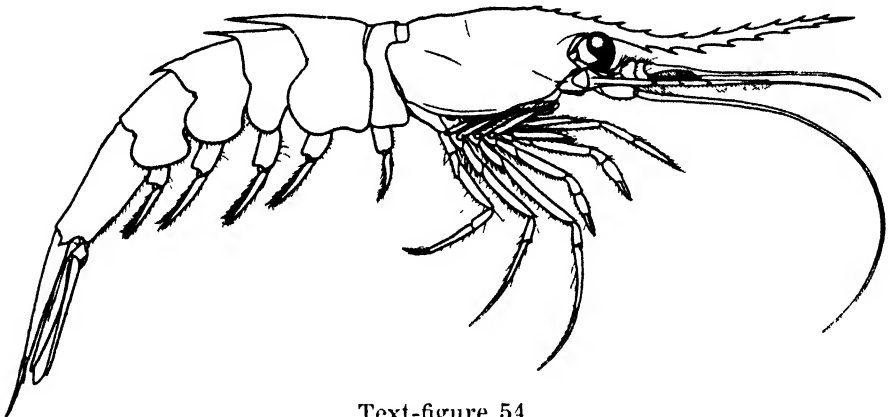
Oplophorus spinicauda Chace, 1936, p. 30.

Diagnosis: Second, third and fourth abdominal somites terminating in a long spine. No spine at postero-lateral angle of carapace. Outer margin of antennal scale spinose. Exopods of all pereiopods foliaceous but not rigid. Telson terminating in an end-piece armed with lateral spines.

Color in Life: Entire integument transparent with scarlet chromatophores scattered over the antennal peduncles, the mouth parts, the pereopods, the basal segment of the pleopods and the sides of the abdomen. The anterior internal thoracic organs scarlet, with a more posterior mass of spectrum red. Eyes blackish-brown.

Remarks: There are nine specimens of this species in the collection; one with a carapace length of 6.2 mm. that is possibly a young male, and the rest, apparently young, with a carapace length of from 4.0 to 5.2 mm. The young male was taken September 15 to 29, 1930, in 600 fathoms, and the young were found in August or September, 1929, July and September, 1930, June and July, 1931, and July, 1934, in depths ranging from 300 to 800 fathoms.

O. spinicauda shows a relationship to members of the genus *Systellaspis* in the form of the telson, the non-rigid exopods of the pereiopods and its relatively soft integument. In other characters as well, such as the presence of spines on the second, third, and fourth abdominal somites rather than on the third, fourth and fifth, the very much reduced molar process of the mandible and the third segment of the endopod of the second maxillipeds vestigial, this species differs strikingly from all other known members of *Oplophorus*.



Text-figure 54.

Oplophorus spinicauda. Young male taken in September, 1930, from 600 fathoms. $\times 3.39$.

Examination of larger series of the species from other localities indicates that there is no appendix masculina on the second pleopod in this form and the endopod of the first pleopod fails to disclose any prominent sexual differences. The sexes can apparently be distinguished, however, by the presence in the male of a broad, shallow indentation in the lower margin of the first abdominal pleuron; in the male, then, the lower margin of this somite is more or less sinuous in outline, whereas in the female and young it is more evenly convex.

There is little doubt in my mind, after examining the type of *O. foliaceus* Rathbun, that these species are identical. Miss Rathbun has informed me that at the time she described the species Milne Edwards' "Recueil de Figures" was not available. The holotype of *Acanthephyra anomala* Boone is a young specimen of *O. spinicauda*, while the paratype mentioned in the description is apparently a young specimen of *O. grimaldii* Coutière.

The following remarks were made by Miss Crane on a specimen of this species:

"The shrimp showed a great deal of spasmodic activity both on the ice and off until placed in formalin twenty-eight hours after it was brought in; at all times it kept up a continuous and vigorous kicking of its pleopods."

Luminescence: The following description of the distribution of photophores in an immature specimen of this species is taken from notes taken from fresh material by Miss Crane.

There is an elongate scarlet patch on a background of pale violet blue situated on the anteroventral surface of the eye, while on the posterior side is another, much larger, scarlet patch. One or both of these may be luminescent. On the thorax, light organs are found on the third maxilliped and the third, fourth and fifth pairs of walking legs. Those on the maxilliped are in two series at the proximal and distal ends of the dactyl, and consist of six and three minute organs respectively; they are posteriorly directed and of a golden color set in scarlet cups. Both the series arrangement and the general appearance bear a striking resemblance to the photophores of *Argyropelecus*. At the proximal end of the carpus of the third walking leg is situated a much larger organ, gold set in scarlet as above, but perfectly round and directed only very slightly downward and forward. On the fourth walking leg are two similar organs, one in a corresponding position and the other at the proximal end of the propodus. Three such organs are present on the fifth leg, two arranged as on the preceding, and the third (much longer—about four times as long as broad) is located on the distal end of the propodus. In addition to the pereopodal organs, an elongate scarlet patch, without any gold visible and possibly glandular in nature, is placed at the base of the last pair of legs beneath the carapace. On the abdomen there is a photophore directed forward and downward at the base of each pleopod; these are of about the same size as those on the thoracic legs, but the scarlet reflector is more prominent than the golden inner part. Finally, there is a smaller, similarly designed light at the inferior base of the uropods.

The following remarks are taken directly from notes made on the same specimen by Dr. Beebe.

"This small shrimp was taken alive in the big wire net at 5-7 knots on June 12th.

"It was invisible in the dark-room until the glass was tapped or the water stirred when a solid luminous spot of pale, bluish-white light shone out steadily. If the shrimp was disturbed further this light vanished and a squirt of luminosity appeared, bright at the source and rapidly fading out as it shot into the water. The visible length seemed about three times the length of the shrimp, and once at least the direction was at right angles downward from the body (about 5:30 P.M.). This phenomenon was repeated four times and it had been noticed before once. This first time (noticed by Miss Crane) there was the steady glow for a moment, then a greater amount of fire shot out than at any of the later times. The last time I saw it, it was as strong as the first. After dark (8 P.M.) the shrimp gave out no light whatever, but the water had a considerable amount of flocculent material on the bottom. This showed no especial structure under the lens."

Geographical Distribution: *O. spinicauda* has been recorded from off the coast of British Honduras, off the coast of Morocco, the Indian Ocean north of Madagascar and south of India and the Hawaiian Islands. In addition, I have seen specimens in the U. S. National Museum from off the east coast of Florida, the West Indies and the Philippine region. In the North Atlantic this species seems to be much more abundant in the West Indian region than in the Bermuda area.

***Oplophorus grimaldii* Coutière.**

Text-fig. 55.

Hoplophorus grimaldii Coutière, 1905a, p. 1114; 1905b, p. 1, fig. 1.*Hoplophorus grimaldii* Coutière, 1925, p. 249, fig. 24.

Diagnosis: Third, fourth and fifth abdominal somites terminating in a long spine. Usually no spine at postero-lateral angle of carapace. Outer margin of antennal scale spinose, and inner margin usually with a barb near the tip. Exopods of all pereopods foliaceous and more or less rigid. Telson terminating in a long spine, but not an end-piece armed with lateral spines.

Measurements: Immature males in which the appendix masculina is shorter than the usual appendix interna have a carapace length varying from 7.3 to 8.0 mm. The largest male in the collection has the carapace 12.2 mm. long and the largest female, 14.2 mm. In the smallest ovigerous female the carapace measures 11.2 mm., and all females exceeding this size are carrying eggs. The smallest specimen has a carapace length of 2.7 mm. In the three specimens in the collection in which the carapace measures less than 3.0 mm. the spine on the third abdominal somite and the rostrum are extremely long, the latter being from two and two-thirds to three times as long as the carapace. The eggs measure 2.8 by 1.8 mm.

Color in Life: Thorax and abdomen white with a heavy wash of scarlet-red chromatophores on the sides; since these are confined on the abdomen to the central part of each somite, a banded appearance is produced. There are golden reflections along the smooth, shiny sides of the carapace. Frequently the abdominal pleura are tinted pale violet. The antennae are transparent except for scarlet-red chromatophores scattered at their bases. Mouth parts brilliant spectrum-red. Pereiopods somewhat lighter, shading to almost transparent scarlet. Pleopods salmon-orange proximally with the exopods and endopods translucent white. Uropods, telson and abdominal spines transparent. Eye dark-brown, the central portion gleaming with reddish gold and orange. Eggs carmine to scarlet-red.

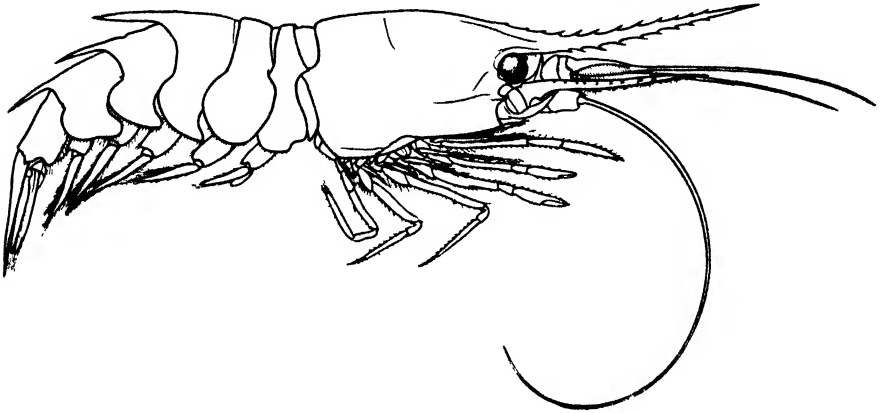
Luminescence: The following notes on the distribution of light organs in this species were made from living material by Miss Crane.

"Behind the eye is a translucent scarlet-red projection from the eye itself enclosing a darker oblong organ; in front a similar but lighter structure is found. One or both are possibly luminescent. On the distal segment of the last maxilliped, extending the entire length of the posterior border (ventral when flexed), is a row of about 45 minute, spectrum-red organs above a long, unbroken line of blue violet which probably acts as a reflector. The two organs, with their segment of the blue line, at the extreme tip are isolated somewhat from the others. A large silvery or golden organ set in purplish-blue occupies most of the interior of the short carpus on the third, fourth and fifth legs. The last (fifth) leg has in addition two organs on the long hand—an elongated oval one proximally about the size of that in the carpal segment, and a much elongated one distally. These leg organs are visible from both the outer and inner side through clear, window-like transparencies in the cuticula. From the inside, though, they appear brilliant scarlet-red as if seen through shiny red cellophane. They cannot be said to be directed in any special direction, except perhaps slightly backwards. Behind the last leg is an elongated transverse bar, the outer half spectrum-red, the inner deep violet-blue. A series of five peculiar tri-colored spots is strung in a broad arc along the carapace, cutting off the lower posterior corner.

On close examination it appears that each spot consists of an upper, upwardly directed bright red light with a violet-blue half-moon reflector placed below it, the interval between light and reflector being white. The abdominal organs consist of six pairs of deep bluish-purple lights set in scarlet-red sockets and placed beneath the epimera on the anterior outer side of the first segment of each pleopod and uropod. They are directed forwards and downwards."

No luminescence was produced in this species by stimulation of live specimens. However, Miss Crane has noted the following of one specimen placed in preservative while still alive:

"Immediately after being placed in alcohol a large quantity of white flocculent material was exuded, apparently chiefly from the posterior part of the ventral side of the thorax, perhaps from the elongated, transverse, violet and red bar previously described."



Text-figure 55.

Oplophorus grimaldii. Male taken in June, 1931, from 300 fathoms. $\times 2.71$.

General Remarks: There are 48 specimens in the collection; 8 males, 19 females, of which 8 are ovigerous, and 21 young.

O. grimaldii can be readily distinguished from the preceding species by the different arrangement of the abdominal spines, but it is more difficult to separate it from *O. gracilirostris* A. Milne Edwards (1881). In general, *O. grimaldii* has the end of the antennal scale barbed on the inner margin and no tooth or spine at the postero-lateral angle of the carapace, whereas *O. gracilirostris* has no barb on the antennal scale and bears a prominent spine at the postero-lateral angle of the carapace. However, four of the present specimens lack the barb on the scale, possibly due to injury, and three of the ovigerous females have a blunt tooth at the postero-lateral angle of the carapace. Fortunately neither of these conditions occurs in the same individual of the present series, but it is not improbable that specimens may be found which might be assigned to either species.

Although there is a well developed appendix masculina in the adult males of this species, there is also a sexual distinction involving the first abdominal pleuron as in the preceding species; in the male, the lower anterior angle of this pleuron is deeply incised so that the angle formed approaches a right angle, while in the female this angle, if present at all, is very obtuse.

One specimen of this species was found in the stomach of the rock fish, *Mycteroperca bowersi*, caught off Challenger Bank, July 30, 1930.

Seasonal Distribution: By far the largest number of specimens of both adults and young were taken in June and July of 1929, 1930 and 1931. Since there was no great concentration of 300 to 500 fathoms tows during these months, it is possible that the species really is most abundant in the Bermuda area in mid-summer. The largest numbers of shallow hauls were made in May, but only one young specimen was found in that month of any year. However, at least one specimen was taken in every month from April to September and ovigerous females occurred in June, July, August and September, the only specimen in which the eggs were eyed being taken in August, 1929.

Vertical Distribution: The largest number of specimens were found at 300, 400 and 500 fathoms, although two or more specimens were taken at every level from 300 to 1,000 fathoms. As this species has been taken at night in the South Atlantic in some numbers only ten meters below the surface, it is possible that a large part of the population occurs above 300 fathoms.

Geographical Distribution: *O. grimaldii* has been recorded from the North Atlantic west of the Madeira Islands, the South Atlantic north of Tristan da Cunha and the Indian Ocean west of Australia. I have also seen specimens from off the east coast of the United States, the Bahamas, south of Japan and northeast of Easter Island in the eastern Pacific.

Family Bresiliidae.

Rostrum well developed. First two pairs of pereopods chelate, shorter than the last three pairs and with an undivided carpus. Last three pairs not abnormally long. Exopods present on the maxillipeds and some or all of the pereopods. Terminal joint of second maxilliped normal, not applied as a strip to the end of the preceding joint. Mandible distinctly, but not deeply cleft.

One genus only is known from the Bermuda area.

Genus *Lucaya* Chace, 1939.

Carapace without a branchiostegal spine. Rostrum unarmed on the lower margin. All five pairs of pereopods provided with exopods, and the last three pairs decrease in length posteriorly. Eyes well pigmented.

There is but one known species.

Lucaya bigelowi Chace.

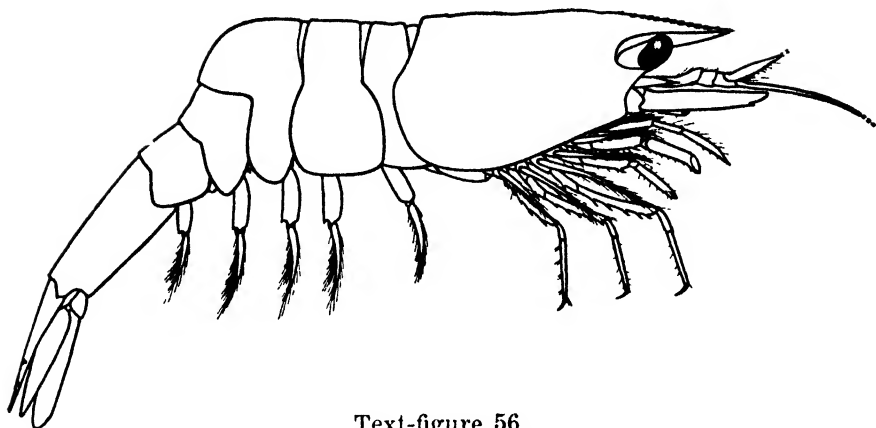
Text-fig. 56.

Lucaya bigelowi Chace, 1939, p. 34.

Diagnosis: Rostrum subquadrate in cross section. Abdomen without carina or armature of any kind; telson with two pairs of dorso-lateral spinules. Antennal scale broad with the blade extending far beyond the outer spine.

Color in Life: Entire animal pale salmon except for the rostrum, antennae and antennal scales which were scarlet.

Remarks: Two males in the present collection bring the total number of recorded specimens of this species to three. One male, with a carapace length of 4.2 mm., was taken in Net 18, April 12, 1929, in 700 fathoms; the other, with a carapace length of 4.7 mm., came from Net 940, September 24, 1930, 1,000 fathoms.



Text-figure 56.

Lucaya bigelowi. Holotype male from the Bahamas. $\times 6.02$.

More complete figures of this species are to be included in the final report on the Crustacea of the *Atlantis* Expeditions to the West Indies.

Geographical Distribution: The holotype came from east of Great Abaco Island in the Bahamas.

Family Pandalidae.

Rostrum prominent and dentate. First pair of pereiopods simple or microscopically chelate. Second pair of pereiopods with the carpus segmented. No exopods on any of the pereiopods. Terminal joint of the second maxillipeds usually applied as a strip to the end of the preceding joint. Mandibles deeply cleft, with a three-jointed palp.

KEY TO THE BERMUDIAN BATHYPELAGIC GENERA OF PANDALIDAE.

Epipods present on all but the last pair of pereiopods
No epipods on any of the pereiopods

Plesionika.
Parapandalus.

Genus *Plesionika* Bate, 1888.

Carapace without lateral longitudinal carinae. Rostrum immovable and armed dorsally with fixed spines and sometimes with movable spines also. Eyes much wider than eyestalks. Stylocerite pointed. Third maxillipeds with an exopod. Epipods present on all but the last pair of pereiopods. Carpus of second pereiopods composed of more than three segments.

One bathypelagic species is known from the Bermuda area.

Plesionika martia (A. Milne Edwards).

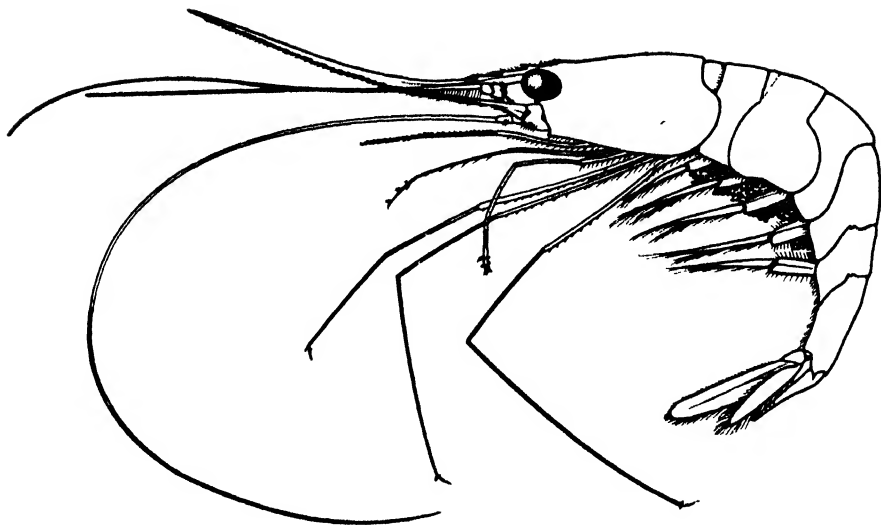
Text-fig. 57.

Pandalus martius A. Milne Edwards, 1883, pl. 21.

Plesionika semilaevis Bate, 1888, p. 644, pl. 113, fig. 3.

Plesionika martia Kemp, 1910, p. 93, pl. 12, figs. 1-4.

Plesionika martia Balss, 1925, p. 278.



Text-figure 57.

Plesionika martia. Ovigerous female (after Kemp, 1910). $\times 0.64$.

Diagnosis: Rostrum longer than antennal scale, dorsally smooth beyond antennular peduncle and regularly serrate below. Hind margin of third abdominal somite rounded. Second pereopods subequal in length.

Color in Life: The Bermuda specimen was pink and white. The following more complete color notes are quoted from Kemp, 1910 (p. 95):

"The carapace and abdomen are thickly sprinkled with bright red chromatophores; the former is dorsally of a dark purple tint, while in the latter the red pigmentation is darker on the posterior portions of each somite. The rostrum is bright red distally, less deeply coloured proximally. The eyes are black, with golden reflections; the antennules are red, and the antenna and antennal scale are more sparsely pigmented with the same colour. The outer maxillipeds and pereopods are more or less thickly spotted with red; the pleopods, telson and uropods are light red. All the fringes of the setae are golden in colour."

Remarks: A single young specimen, having a carapace length of 7.0 mm., was taken in Net 860, September 8, 1930, in 600 fathoms.

This is the first record for this species in the western Atlantic and one of the very few specimens ever taken with a mid-water net. Apparently *P. martia* generally remains on or near the bottom as indicated by the long, slender pereopods, since most of the known specimens have been taken with a dredge or trawl. However, Balss records an ovigerous female captured by the *Valdivia* in the Gulf of Guinea with a vertical net between 437 fathoms and the surface.

Geographical Distribution: *P. martia*, including its varieties, has been found off Ireland, in the Bay of Biscay, the Mediterranean Sea, the Gulf of Guinea off the west coast of Africa, off the Cape of Good Hope, off the east coast of Africa from Tanganyika to Italian Somaliland, in the Arabian Sea, the Andaman Sea, the Malay Archipelago, Sagami Bay, Japan, the Fiji Islands, off Sydney, Australia, the Kermadec Islands and the Hawaiian Islands.

Genus ***Parapandalus*** Borradaile, 1900.

Carapace without lateral longitudinal carinae. Rostrum immovable and armed dorsally with fixed spines and sometimes with movable spines as well. Eyes much wider than eyestalks. Stylocerite pointed. Third maxilliped with an exopod. No epipods on any of the pereopods. Carpus of second pereopods composed of more than three segments.

Only one bathypelagic species is known from the Bermuda area.

Parapandalus richardi (Coutière).

Text-figs. 58-61.

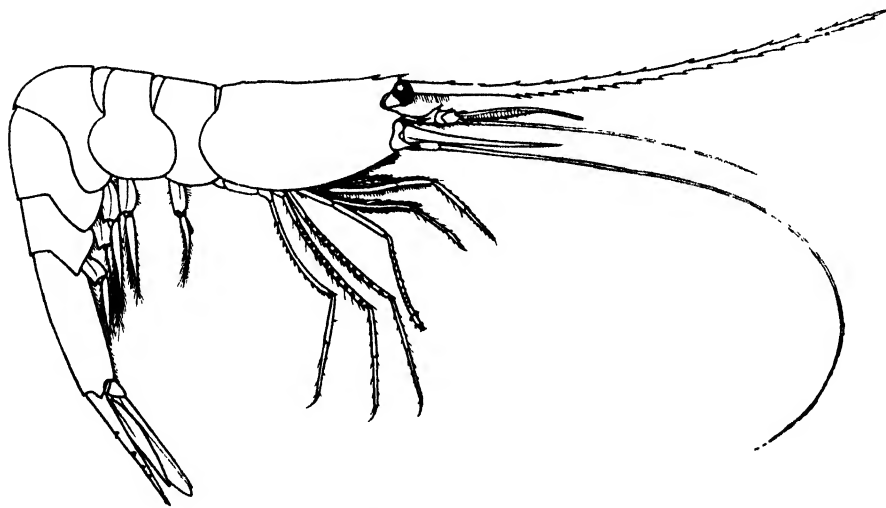
Pandalus (*Stylopandalus*) *Richardi* Coutière, 1905b, p. 18, fig. 6.

Parapandalus Richardi de Man, 1920, pp. 108 and 140.

Diagnosis: Rostrum about three times as long as carapace and armed with more or less widely spaced teeth along the entire length of its dorsal margin, including two larger teeth above the eye. Third abdominal somite at middle of its posterior margin with a slender, movable spine. Sixth abdominal somite at least three times as long as high and about two and two-thirds times as long as fifth somite.

Measurements: The smallest recognizable males in which the appendix masculina is no more than a bud have a carapace length of 4.2 mm., and the smallest ovigerous females have the carapace 5.8 mm. long. In ovigerous females in which the eggs are not eyed, the average carapace length is 6.7 mm., whereas in those in which the eggs are eyed this figure is 6.5 mm.; this may be due to a slight shrinking of the integument prior to the moult following the hatching of the eggs. The carapace of the largest male measures 7.2 mm., and of the largest female 7.5 mm. In the smallest specimen seen the carapace is 2.9 mm. long, but in most of the young specimens this measurement exceeds 3.5 mm.

Color in Life: In mature individuals, the entire prawn is bright scarlet, though paler on the abdomen where the color is resolvable into individual



Text-figure 58.

Parapandalus richardi. Male taken in June, July or August, 1931, from 500 fathoms. $\times 3.05$.

chromatophores on a white background. In young specimens, the anterior part of the body as far back as the third abdominal somite dorsally and the fourth pereopod ventrally is bright scarlet including the appendages; behind this the prawn is white, with the line of demarcation between the two regions yellowish sprinkled with scarlet chromatophores; there is a faint sprinkling of chromatophores along the sides of the abdomen also. Eyes brownish-black. Eggs pomegranate purple.

General Remarks: There are 404 specimens of this species in the collection; 166 males, 195 females, of which 105 are ovigerous, and 43 young. Of the ovigerous females, 30 carry eggs in which the eyes are developed.

TABLE 1.
SEASONAL DISTRIBUTION OF *P. richardi* IN 1929.

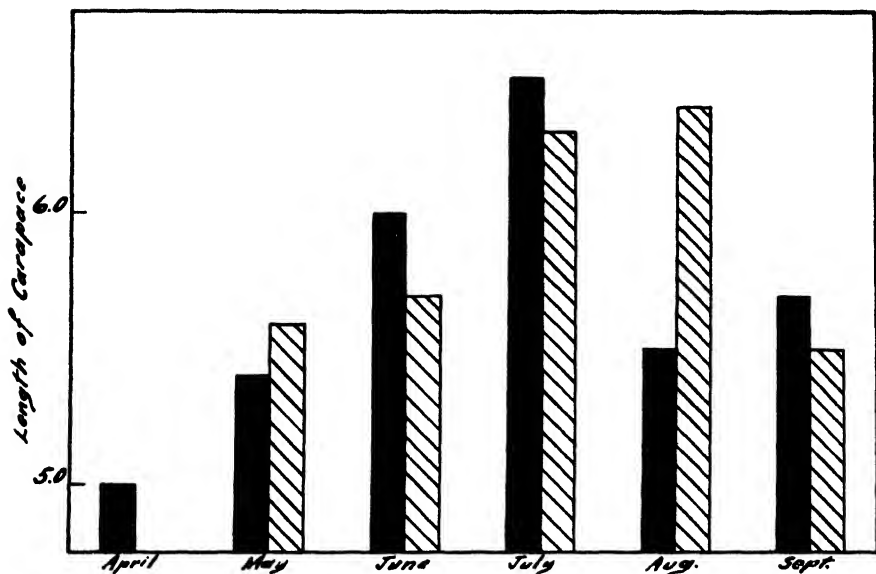
Carapace Length (mm.)	April	May	June	July	Aug.	Sept.
3.0	—	—	—	—	—	—
3.5	—	1	—	1	4	1
4.0	4	—	4	—	4	6
4.5	7	1	2	—	1	4
5.0	12	3	5	1	1	2
5.5	6	4	—	1	1	—
6.0	4	7	20	6	3	8
6.5	1	—	21	20	4	5
7.0	—	—	3	17	5	7
7.5	—	—	—	—	1	1

TABLE 2.
SEASONAL DISTRIBUTION OF *P. richardi* IN 1930.

Length Carapace (mm.)	April	May	June	July	Aug.	Sept.
3.0	No tows made in April	—	—	—	—	1
3.5		1	—	—	—	2
4.0		—	1	—	—	7
4.5		4	1	1	—	2
5.0		10	3	1	1	4
5.5		8	2	—	—	4
6.0		7	8	11	—	3
6.5		2	3	12	3	4
7.0		1	—	7	—	10
7.5		—	—	—	1	1

TABLE 3.
VERTICAL DISTRIBUTION OF *P. richardi*.

Carapace Length (mm.)	Fathoms							
	300	400	500	600	700	800	900	1,000
3.0	—	1	—	—	—	1	—	—
3.5	—	1	3	—	—	3	1	2
4.0	3	2	12	2	1	1	1	2
4.5	—	4	10	1	—	—	1	5
5.0	1	8	16	10	3	4	1	3
5.5	1	1	11	4	7	1	2	1
6.0	—	3	25	19	11	6	9	9
6.5	3	4	31	25	14	5	6	9
7.0	3	6	34	10	14	5	1	4
7.5	—	—	3	3	1	—	—	—

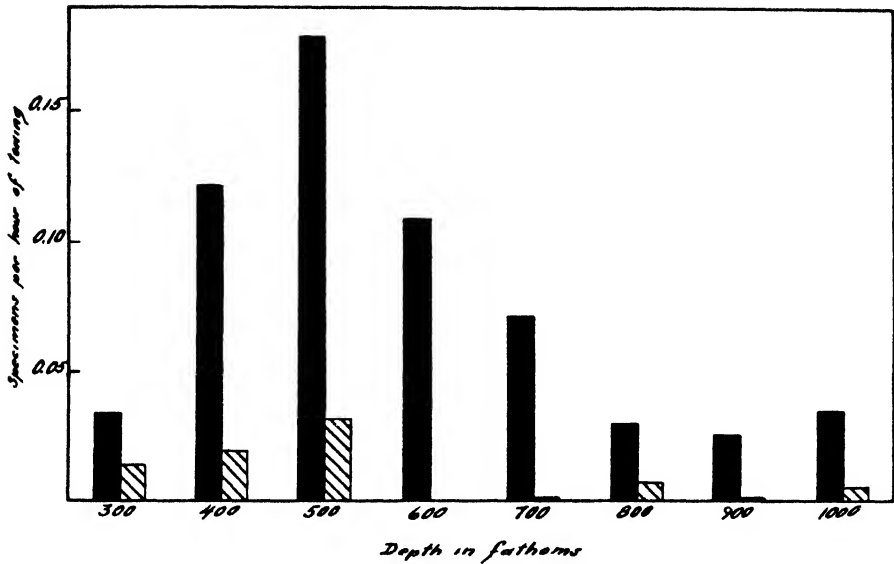


Text-figure 59.

Average carapace lengths of specimens of *Parapandalus richardi* taken in 1929 (solid bars) and 1930 (hatched bars).

This species is very similar to *P. zurstrasseni* Balss (1914) from the Indo-Pacific region. Whether or not they are identical can be determined only when more specimens of the latter species are discovered. *P. zurstrasseni* apparently lacks the slender spine on the third abdominal somite, but this is frequently broken off in specimens of *P. richardi*.

Seasonal Distribution: Analysis of the tows made in 1929 and 1930 reveals a very definite increase in the proportion of ovigerous females from about 10 per cent. of all females in April and May to 70 or 80 per cent. in July, August and September. However, as shown in Tables 1 and 2 and in Text-fig. 59, this is largely due to the fact that most of the females present in the spring are too young to bear eggs. If only those females in which the carapace exceeds 6.0 mm. are considered, it is found that from 60 to 100 per cent. are ovigerous and 15 to 30 per cent. are carrying eggs in which the eyes are visible in every month in which towing was done. The seasonal distribution of the size groups shown in Text-fig. 59 indicates that one group matures in July or August and that another group of younger individuals appears at this time. Study of the tables, however, shows that this lowering of the average carapace length is due fully as much to the decrease in the numbers of large specimens as to the increase of the small. The graph might lead to the assumption that the season was retarded somewhat in 1930 over that of 1929, but this is due largely to the increase in average size in August, 1930, and in this month only five specimens were taken, certainly not enough to yield significant results. It is difficult to account for this seasonal distribution and, except for the fact that a similar trend was found in both 1929 and 1930, little importance would be laid on results gained from such a comparatively small number of specimens. Whether this trend is caused simply by the migration of fully mature individuals through the towing area in greatest numbers in June and July or whether it is due to the normal growth of more than one age class can hardly be determined from these data. There is evidence that swarming occurs to some extent in this species since 65 of



Text-figure 60.

Vertical distribution of adults (solid bars) and young (hatched bars) of *Parapandalus richardi*.

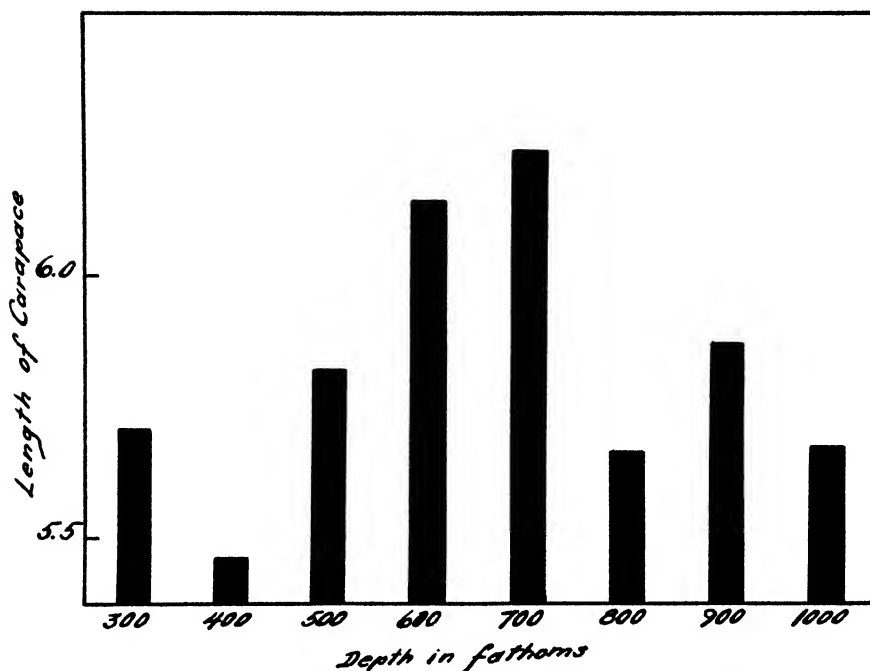
the specimens were taken in only seven nets; one in May, two in June and four in July. This, of course, may be due merely to a general increase in the number of individuals for a short period rather than actual swarming, but it has a definite effect on the results.

Vertical Distribution: The vertical distribution of the total catch is given in the following table:

Fathoms	Males	Females	Young
300.....	4.....	4 (3 ovig.)	3.....
400.....	12.....	14 (3 ovig.)	4.....
500.....	59.....	69 (40 ovig.)	23.....
600.....	34.....	40 (20 ovig.) .....	.....
700.....	22.....	28 (17 ovig.)	1.....
800.....	11.....	10 (4 ovig.)	5.....
900.....	8.....	11 (5 ovig.)	1.....
1,000.....	14.....	18 (11 ovig.)	5.....

Reduced to the number of specimens per towing hour, these data produce the graph shown in Text-fig. 60, and the average carapace length of the specimens at each depth is shown in Table 3 and Text-fig. 61. The optimum level for the species is at about 500 fathoms and, since open nets were employed, it might be assumed that specimens taken in over 800 fathoms were captured actually at higher levels as the nets were taken in; the unexpectedly large proportion of young specimens at these deep levels would point to the same conclusion. However, this question can be settled only by the use of closing nets. As will be seen from the table, ovigerous females were dispersed fairly uniformly from 300 to 1,000 fathoms, and the same applies to those carrying eyed eggs. As in *Systellaspis debilis*, there is no indication that males are proportionately more abundant at the deeper levels.

Geographical Distribution: The species has been previously recorded only from the Canary Islands and west of the Madeira Islands. Since it has not been taken by any of the expeditions in the northern part of the North Atlantic, *P. richardi* is probably a warm water form.



Text-figure 61.

Variation in the average carapace length of catches of *Parapandalus richardi* made at 100 fathom intervals.

Family Physetocaridae, fam. nov.

Rostrum present as a broad prolongation of the carapace. First pereopods simple. Second pereopods chelate, with the carpus segmented. No exopods on the third maxillipeds or any of the pereopods. Terminal joint of the second maxillipeds not applied as a strip to the end of the preceding joint. Mandible without an incisor process or palp.

Genus *Physetocaris*, gen. nov.

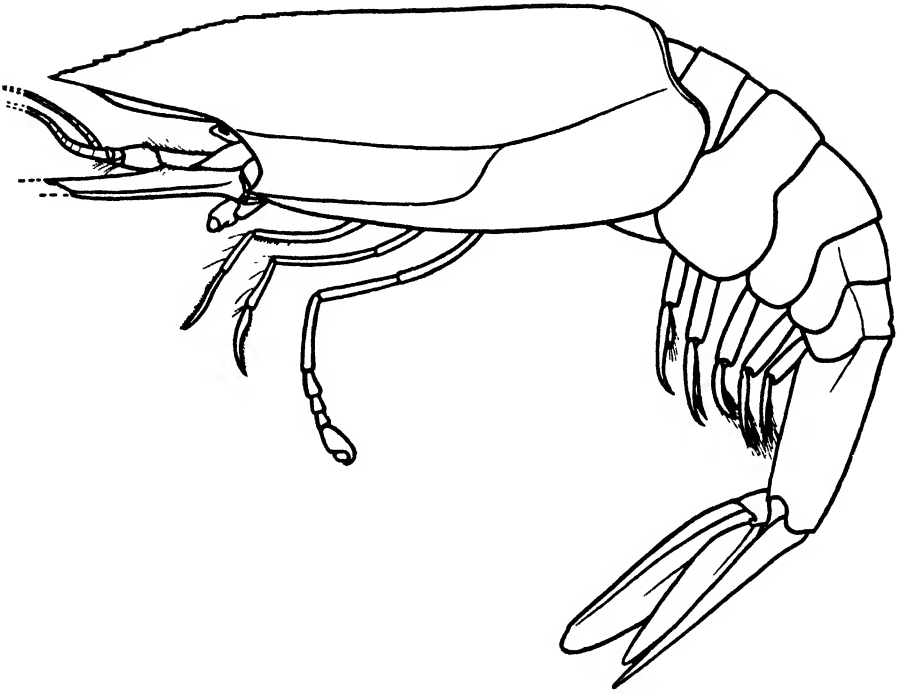
Carapace greatly inflated. Carpus of second pereopods consisting of four segments; chela flattened with a very short, broad dactyl. Branchial formula as follows:

	VII	VIII	IX	X	XI	XII	XIII	XIV
Podobranchiae	ep.	ep.	ep.	ep.	ep.	ep.		
Arthrobranchiae								
Pleurobranchiae				1	1	1	1	1

Physetocaris microphthalmia, sp. nov.

Text-figs. 62 and 63.

Types: Holotype female (?) Cat. No. 30,523, Department of Tropical Research, New York Zoological Society; Net 798; July 15, 1930; 600 fathoms.



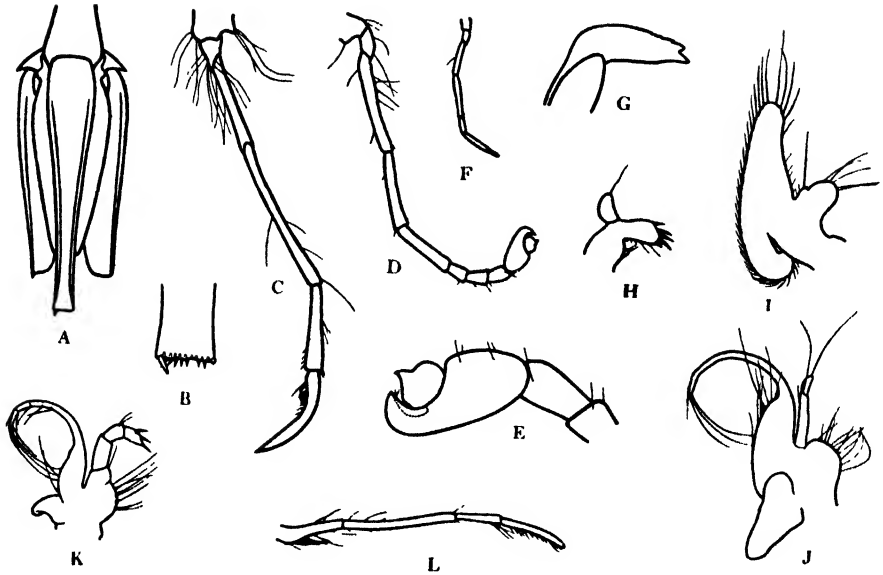
Text-figure 62.

Physetocaris microphthalmus. Holotype. $\times 6.00$.

One female (?); Net 983, 990, 997, 1003, 1014, 1015, 1016, 1102, 1108, 1115, 1121, 1131, 1137 (?), 1138 (?), 1144, 1149 or 1150; June 2 to August 8, 1931; 500 fathoms.

Diagnosis: Carapace with two lateral carinae. Abdomen without any dorsal carinae or spines. Telson deeply sulcate dorsally and broadly truncate at the tip. Eyes very small and set on outside of stalks.

Description: Integument extremely thin and fragile. Carapace markedly inflated dorsally and anteriorly to form a very broad, inflated rostrum. The dorsal margin is carinate for its entire length and minutely denticulate on the anterior third of its length. In addition to the dorsal carinae there is a lateral carina originating behind the eye, which passes backward and slightly downward for about three-fifths of its length and then turns upward and terminates just before reaching the hind margin of the carapace. A second lateral carina starts at the branchiostegal spine, runs backward nearly parallel with the first for about half the length of the carapace, then turns upward and joins the first carina at the point where the latter bends upward. Orbit not defined, the raised line bordering the lower lateral margin of the rostrum forming a smooth curve and terminating in the prominent branchiostegal spine. Abdomen without any dorsal carina or spine on any somite, the only ornamentation being a raised ridge at the junction of the terga and pleura on the fourth and fifth somites; this ridge also extends onto the anterior part of the sixth somite. The sixth somite is about three and one-half times as long as the fifth. Telson longer than the sixth somite, deeply sulcate dorsally and broadly truncate at the tip where it is armed with a row of ten small spines, the outermost pair being about twice as long as the eight central ones. In the holotype, the tip of the telson is slightly concave rather



Text-figure 63.

Physetocaris microphthalma. A. Telson and uropods. B. Tip of telson. C. First pereopod. D. Second pereopod. E. Chela of second pereopod. F. Fifth pereopod. G. Mandible. H. First maxilla. I. Second maxilla. J. First maxilliped. K. Second maxilliped. L. Third maxilliped.

than nearly straight as in the paratype (Text-fig. 63 B). Eyes small and nearly hidden beneath the rostrum; the minute cornea is set at the antero-external angle of the stalk so that the latter extends beyond the cornea. Stylocerite is a broad, fleshy lobe of the first segment of the antennular peduncle and its outer spine reaches about to the distal third of that segment. Antennal scales damaged in both specimens; there is a small spine on the peduncle at the base of the scale. First pereopod with a sickle-shaped dactyl. Second pereopod with the carpus divided into four joints, the first of which is nearly as long as the combined length of the other three; chela flattened and provided with a curious, broad dactyl (Text-fig. 63 E). Third and fourth pereopods missing. Fifth pereopod reduced and simple (Text-fig. 63 F). The mouth parts are shown in Text-fig. 63 G-L. The mandible lacks both an incisor process and a palp and the remaining mouth parts are correspondingly reduced. The first three segments of the second maxilliped are more or less fused and the terminal segment bears three prominent spines and is applied normally to the end of the preceding joint.

Measurements: Carapace of holotype, measured from the base of the eyestalk, measures 9.2 mm. The paratype is somewhat smaller, having a carapace length of only 6.2 mm.

Color in Life: Carapace translucent white over a deep red organ (possibly ovaries). Abdomen scarlet with red at the base of the pleopods.

Remarks: In the absence of adult males or ovigerous females it is, of course, possible that this prawn may be a larval form. The fully developed appendages and lack of exopods do not bear out this possibility, however. Whether it is a larval stage or not, its systematic position is extremely obscure. It has been impossible to accommodate it in any known caridean family and even its relative position among the established families is un-

certain. There is little doubt that it is one of the most specialized bathypelagic carideans known, and it apparently shows affinities with the Processidae and the Cragonidae as evidenced by the reduced gill structure, the form of the mandibles and other mouth parts, the simple first pereopods (as in one of the first legs in *Processa*) and the multiarticulate carpus of the second pereopods. The chela of the second pereopod is unlike that found in any other caridean except possibly that on the first pereopod in the genus *Discias*; obviously, however, its relation to *Discias* is remote.

GENERAL DISCUSSION AND SUMMARY.

Taxonomy: The name of the family to which the largest number of bathypelagic carideans belong has been the cause of considerable confusion; at various times it has been known as the *Oplophoridae*, *Ephyridae*, *Miersiidae* and *Acantheephyridae*. Although the latter name, which I have employed previously, seems the more suitable, it now appears advisable to use the name *Oplophoridae* since Kingsley's use of the subfamily name *Oplophorinae*, in 1878 and 1879, antedates all others and logically proposes *Oplophorus* as the type genus, even though Kingsley originally erected the subfamily to include *Oplophorus elongata* (= *Xiphocaris elongata*, an atyid). In 1879 (p. 416) he proposed *Ephyrinae* as a subfamily of the *Atyidae*, whereas his *Oplophorinae* (p. 426) was included in the *Palaemonidae*. *Ephyra*, the type genus of the *Ephyrinae*, was proposed by Roux, 1831, for the type species, *Alpheus pelagicus* Risso, 1816, and later replaced with *Miersia* by Kingsley, 1879, since Roux's name was preoccupied. *Miersia pelagica* is apparently unknown to modern carcinologists, but it seems not unlikely that Risso's species may be the same as the form now known as *Acantheephyra pulchra* A. Milne Edwards, 1890. Risso's crude figure is obviously incorrect as regards the form of the rostrum, and there is nothing in the description which would not apply equally well to *A. pulchra* except that all of the abdominal somites are said to be sharply carinate and no mention is made of the presence of exopods on any of the pereopods. Even if these discrepancies are overlooked, however, Risso's description can never be used with any certainty and, since the type is probably not extant, the best procedure seems to be to discard *Ephyra* and *Miersia* entirely and use the name *Oplophoridae* for the family as it is known today.

There has also been some difference of opinion as to the proper spelling of the name of the type genus. The correct transliteration is, of course, *Hoplophorus*, but even though the aspirate is seldom if ever used in modern French and so might well have been overlooked by Milne Edwards, there is no choice under the present rules of nomenclature but to preserve the original orthography, *Oplophorus*, as proposed by the original author.

It is likely that future investigations will reveal that the systematics of the *Oplophoridae* as known at present are very inadequate. *Systellaspis* and *Oplophorus* are more or less well defined genera and there is little likelihood of confusing the species of those genera with any other. Likewise, the more typical members of *Acantheephyra* cause little trouble, but the line of division between *Acantheephyra* and the three other genera, *Hymenodora*, *Notostomus* and *Ephyrina*, is not sharply defined. Although there is little chance of confusing the species of *Hymenodora* with those of *Acantheephyra*, it is difficult to find any character of systematic importance for distinguishing the two groups. The reverse is true of the division between *Acantheephyra* and *Notostomus*; it is almost impossible to assign species like *Acantheephyra gracilipes* and *Notostomus compsus* to the proper genera at a glance, but the form of the mandible reveals a good diagnostic character. The genus *Notostomus*, as here defined, is a very heterogeneous group. It may be necessary at some future date to split off the species of the *N.*

vescus group under the inappropriate name, *Meningodora*. Possibly this group, even as known at present, deserved at least subgeneric recognition, but I have not made this distinction because of the way in which the gap between the two groups is filled by such species as *N. mollis* and *N. distirus*. *Ephyrina* is another easily recognizable genus which exhibits no character of great systematic importance to separate it from *Notostomus*; the form of the mandibles and the presence of a lateral ridge on the carapace ally it so closely to *Notostomus* that the broadened form of the pereopods is the only distinctive character separating it from that genus. *Notostomus*, then, is the genus which causes the greatest trouble; it is made up of about fifteen species at present and more are being found by nearly every expedition. Until our knowledge of this genus is more nearly complete, it is probably advisable to follow the systematic scheme already established for the family.

Since so many of the bathypelagic Caridea belong to relatively primitive groups, it is surprising to find such a highly evolved new form as *Physetocaris* in such a habitat. Although this animal appears to be one of the most specialized carideans known, as evidenced by the absence of exopods, the reduced gill series, the simplified mouth parts and the jointed carpus and complex chela of the second pereopods, it has apparently been able to assume a pelagic mode of life by adding to its buoyancy by means of a membranous integument and an inflated carapace.

Summary of Quantitative Results: The following table lists the species taken during the expeditions, arranged according to the number of adult specimens procured.

Species	Adults	Young
<i>AcanthePHYra purpurea</i>	1705	2867
<i>Systellaspis debilis</i>	1037	912
<i>Parapandalus richardi</i>	361	43
<i>Hymenodora gracilis</i>	279	1550
<i>Notostomus miccylus</i>	120	25
<i>Notostomus vescus</i>	78	74
<i>AcanthePHYra haeckeli</i>	71	146
<i>Parapasiphaë sulcatifrons</i>	36	461
<i>AcanthePHYra stylo-rostrata</i>	32	54
<i>Oplophorus grimaldii</i>	27	21
<i>Notostomus mollis</i>	12	44
<i>Notostomus robustus</i>	9	11
<i>Leptochela bermudensis</i>	8	8
<i>Notostomus marptocheles</i>	6	9
<i>Ephyrina bifida</i>	5	65
<i>Notostomus compsus</i>	3	—
<i>Parapasiphaë macrodactyla</i>	2	28
<i>Systellaspis braueri</i>	2	11
<i>Pasiphaea hoplocerca</i>	2	5
<i>Notostomus distirus</i>	2	—
<i>Lucaya bigelowi</i>	2	—
<i>Physetocaris microphthalma</i>	2	—
<i>Oplophorus spinicauda</i>	1	8
<i>AcanthePHYra brevirostris</i>	1	5
<i>Pasiphaea liocerca</i>	1	—
<i>AcanthePHYra gracilipes</i>	1	—
<i>AcanthePHYra</i> , sp. ?	—	8
<i>AcanthePHYra eximia</i>	—	3
<i>Parapasiphaë</i> , sp. b.	—	2
<i>AcanthePHYra acutifrons</i>	—	2
<i>Notostomus westergreni</i> ?	—	2
<i>Parapasiphaë</i> , sp. a.	—	1
<i>AcanthePHYra curtirostris</i>	—	1
<i>Notostomus perlatus</i> ?	—	1
<i>Ephyrina hoskynii</i>	—	1
<i>Plesionika martia</i>	—	1

Acantheephyra purpurea and *Systellaspis debilis* are by far the commonest species in this area but even these species, at the levels at which each was most abundant, were captured at the average rate of only one adult for every 1.7 and 2.1 hours of towing respectively. In the case of the tenth species in the list, *Oplophorus grimaldii*, 39 hours of towing were required for every adult specimen taken at 300 fathoms, the optimum level for that species in the daytime. A one meter net is far from being perfectly efficient in straining a one meter column of water, but if the assumption of 100 per cent. efficiency is allowed and if the nets are drawn through the water at the rate of one knot, which is probably conservative, these results would indicate an average concentration of the commonest caridean, *Acantheephyra purpurea*, of one adult in every 88,269 cubic feet of water at 700 fathoms which is the optimum level for that species. This gives some indication of the rarity of many of the species toward the end of the above list. Several are probably only accidental strays into this region from some other oceanic area, but the total results of all past expeditions seem to indicate that certain bathypelagic species are everywhere very rare. It is unwise, however, to make such general statements when one realizes how little of the volume of the sea has been investigated. Many species, now considered rare, may prove to be relatively common when their center of concentration is discovered. This point is clearly emphasized by the fact that the fifth species in order of abundance in the Bermuda area, *Notostomus miccyllus*, was previously unknown.

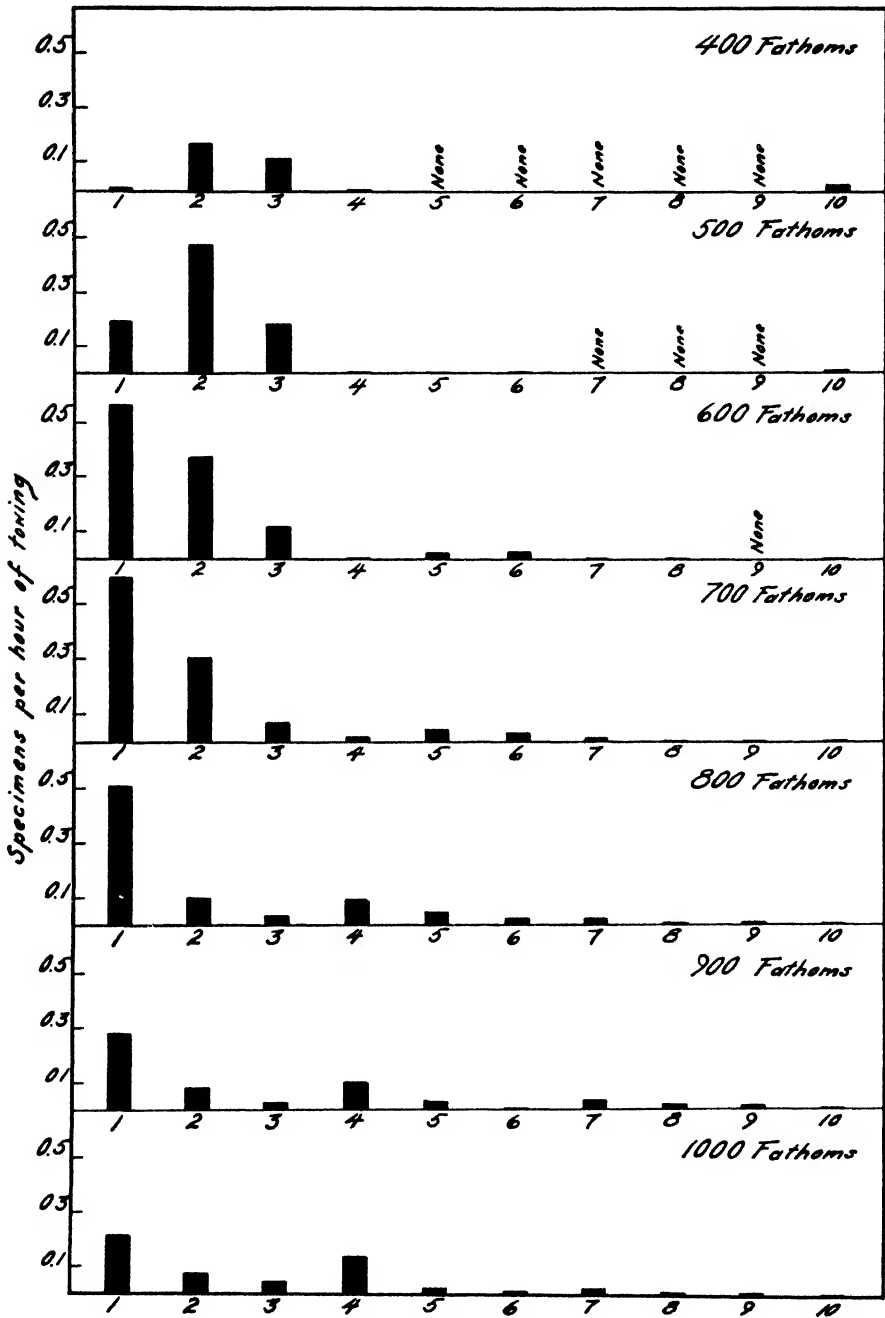
Text-fig. 64 may be useful in picturing the relative abundance of adults of the ten commonest species in the Bermuda area at each level from 400 to 1,000 fathoms. The fact cannot be stressed too strongly that this graph is applicable only to the particular region in which this work was done, or at most to the Sargasso Sea. During the course of several cruises of *Atlantis* of the Woods Hole Oceanographic Institution to the Sargasso Sea and to waters off the continental shelf to the west and north of the Gulf Stream, species common to both areas were found in much greater depths in the Sargasso area than on the coastal side of the Stream.

One of the interesting but unexplainable points brought to light by the collection is the change in the ratio between the sexes of certain species with an increase in depth. In both *Acantheephyra purpurea* and *Hymenodora gracilis*, males were proportionately more numerous near the lower limits of their range than they were nearer the surface. On the other hand, in two other species which were represented by an equally large number of specimens, *Systellaspis debilis* and *Parapandalus richardi*, no such change in the sex ratio was found. Whether the females of the first two species are for some reason more buoyant than the males or whether the phenomenon has some more involved explanation can hardly be decided at present. The logical conclusion that females with eggs are found nearer the surface is not confirmed by this material.

As practically all of the tows were made in the daytime, the collection fails to increase our knowledge of the diurnal vertical migration of these forms. Only in the case of *Leptochela bermudensis* was there evidence of diurnal migration. Although the number of specimens involved was small, this species was found at the surface in the evening but only at 400 and 700 fathoms during the daytime.

No definite evidence of any seasonal distribution could be discovered, with the exception of *Parapandalus richardi* (see remarks on seasonal distribution under that species). In all other cases where significant numbers of specimens were available, no seasonal fluctuation of any sort could be detected over the period in which towing was done. Oviparous females of most species were taken in every month from April to September.

Geographical Distribution: As noted above, that portion of the sea through which nets have been drawn is extremely small and our knowledge



Text-figure 64.

The vertical distribution of adults of the ten commonest species of bathypelagic Caridea in the Bermuda area during the daytime. 1. *Acantheephyra purpurea*. 2. *Systellaspis debilis*. 3. *Parapandalus richardi*. 4. *Hymenodora gracilis*. 5. *Notostomus miccylus*. 6. *Notostomus vascus*. 7. *Acantheephyra haeckelii*. 8. *Parapasiphaë sulcatifrons*. 9. *Acantheephyra stylostrata*. 10. *Oplophorus grimaldii*.

of oceanic barriers to the dispersal of bathypelagic organisms is correspondingly inadequate. From such distributional data as are available at present, it is obvious that the temperature and chemical composition of the sea have a much greater effect on the dispersal of such species than have any land barriers. Probably, then, oceanic currents will be found to delimit faunistic zones in the ocean depths much as do mountain ranges, deserts and bodies of water on land. In most cases, it is certainly misleading to define the limits of pelagic organisms on the basis of parallels of latitude and longitude. In reviewing the known distributions of the species of Caridea found off Bermuda, I have been forced to employ the more or less arbitrary regions listed below. These areas are actually regions in which more or less extensive investigations of the bathypelagic fauna have been carried on and if any of them also represent definite oceanic faunistic regions it is largely accidental. The following is a list of the zones from which species taken by the Bermuda Expeditions have been recorded previously, with the figures in parenthesis representing the numbers of species common to both those areas and to Bermuda.

- Sargasso Sea (4)
- North Atlantic (north and west of the Gulf Stream) (6)
- Off the coasts of Ireland (5)
- Eastern North Atlantic (Bay of Biscay to Cape Verde Ids.) (11)
- Mediterranean Sea (2)
- Bahamas and the West Indies (9)
- Equatorial Atlantic (11)
- South Atlantic (2)
- Off the Cape of Good Hope (6)
- Indian Ocean (15)
- Malay Archipelago and Philippine Ids. to Japan (9)
- South Pacific (4)
- Hawaiian Islands (5)
- Eastern Pacific (California to Peru) (6)

In many instances this list is no more than a key to the amount of exploration carried on in each of these zones; there is little doubt that additional towing in the West Indian region and in the equatorial Atlantic will reveal more forms found also at Bermuda. The small number of species previously known from the Sargasso Sea is due entirely to the lack of reports on that area, but there is an indication that the Sargasso fauna extends well to the east in the region of the Bay of Biscay and off the coast of Africa; several forms found both in that area and off Bermuda have not been recorded from north and west of the Gulf Stream or off the coasts of Ireland. The one striking fact illustrated by the list is the unimportance of distance or land barriers when dealing with the distribution of pelagic animals; even though the number of species may have been proportionately increased by the amount of deep-sea work carried on there, the fact that no less than fifteen of the twenty-five species from Bermuda, which had been described heretofore, are also found in the Indian Ocean should be of particular interest to the student of zoogeography.

Color of Bathypelagic Caridea: So much has been written on the color of deep-sea Crustacea that there is little necessity for reviewing the subject here. The excellent color notes on the Bermuda material supplied by Miss Crane reaffirms the well established fact that most bathypelagic prawns are of some shade of red in life. All of the species of *Acantheephyra* in which the color was noted, as well as *Pasiphaea liocerca*, *Parapasiphae sulciferons*, *Notostomus robustus*, *Hymenodora gracilis* and *Systellaspis debilis*, have the body entirely scarlet or scarlet-red. Certain of the species of *Notostomus* of the *N. rescus* group have the abdomen scarlet but the carapace much deeper in color, at times nearly black. *Lucaya bigelowi* is unique in being pale salmon in life. There is another group of species, many of which are found relatively near the surface, in which the scarlet coloring

is reduced to patches or even to isolated chromatophores. This tendency is noted in *Notostomus miccylus* and *Parapandalus richardi* which have the carapace evenly scarlet but the abdomen, especially in immature specimens which frequent shallower depths, heavily spotted with scarlet. The same condition is noted in young specimens of *Systellaspis debilis*, and even in mature specimens of this species which have not attained their maximum size the uropods are often transparent. In *Leptochela bermudensis*, *Oplophorus spinicauda*, *Oplophorus grimaldii* and *Plesionika martia*, all of which may be found relatively near the surface, the entire animal is more or less transparent with scattered scarlet markings or dots. Specimens of *Leptochela bermudensis* which were kept alive for some time after their capture showed a slight deepening of color after several hours; it is not inconceivable that some species undergo a certain amount of color change depending upon the amount of light to which they are exposed.

Luminescence: Four of the bathypelagic Caridea of the Bermuda area are shown to be luminescent from notes made on living material; these species are *Leptochela bermudensis*, *Systellaspis debilis*, *Oplophorus spinicauda* and *O. grimaldii*. All of these forms apparently possess photophores, or dermal light organs of a definite structure, although this conclusion could not be substantiated in *Leptochela bermudensis*. Only from this latter species, however, could luminescence of the photophore type be produced. To my knowledge, the photophores of captured specimens of *Systellaspis debilis* have never been seen to emit light, but that such is their function can hardly be doubted, and Beebe (1934, p. 304) records the following observation made from the bathysphere, "Again, one good-sized shrimp at 1300 feet had six or eight scattered lights, and one long, slit-like light near the center of its body, which identified it with almost complete certainty as *Systellaspis debilis*." Although the presence of a transverse, slit-like organ does not necessarily prove that the species observed was *S. debilis* since several oplophorids have similar photophores behind the fifth pereopods and those in *Oplophorus grimaldii* are very like the comparable organs in *S. debilis*, these observations lend further assurance that these types of photophores are functional light organs. During one of the cruises of *Atlantis* to the Sargasso Sea, *S. debilis* was obtained in considerable numbers and it was possible to keep them alive for at least a week by refrigeration, but all attempts to shock them into producing light were futile. Similar experiments tried on living material of *Oplophorus spinicauda* and *Oplophorus grimaldii* from the present collection were likewise negative. One of the theories advanced to explain the function of these light organs suggests that they are used as specific recognition signs to enable individuals to find specimens of the opposite sex of the same species. Is it not possible, if such is the explanation, that the ability to produce light may be controlled by the ripening of the eggs and sperm? This would greatly reduce the likelihood of seeing the photophores light up in any given specimen. Since these animals can be obtained in considerable numbers in the Bermuda area and since they can be kept alive and apparently healthy for some length of time by regulating the temperature of the water, it is to be hoped that this theory may be checked in the near future.

Another type of luminescence noted in bathypelagic Caridea is the production of the so-called "luminous cloud." This appears to be a purely defensive mechanism whereby a prawn, when startled, can emit a cloud of luminous material from some internal gland. This spectacle was seen in *Systellaspis debilis* and *Oplophorus spinicauda* (see notes under that species) among the Bermuda material. Dr. Beebe assures me that this phenomenon was repeatedly observed in specimens of the former species and has very kindly provided me with a photograph of a specimen which had been seen to emit such a cloud; there is no doubt that it belongs to this species. Miss Crane has also observed that on many occasions when specimens of this species were placed in alcohol, a mass of flocculent material was immediately

ejected. On several occasions this was tested in the dark-room and found to be fluorescent. Curiously enough, Miss Crane has also noted the presence of this flocculent material when specimens of *Acantheephyra* were put in preservative.

Dr. Beebe (1934, p. 304) records as follows the results of his observations on this subject made during descents of the bathysphere: "Whereas the photophore-like organs of euphausiids may serve chiefly as recognition marks, or other non-defensive capacities, the luminous matter [of large, *Acantheephyra*-like shrimps] was obviously discharged only when a shrimp was startled, as when it bumped against the bathysphere window. When this happened, a rocket-like burst of fluid was emitted with such violence that the psychological effect was that of a sudden explosion. This occurred time and again at the lower levels, and I learned to distinguish two separate types of discharge, one uniformly luminous, the other dimmer but interspersed with dozens of brilliant stars and pinheads. For an instant the shrimp would be outlined in its own light—vivid scarlet body, black eyes, long rostrum—and then would vanish, leaving behind it the confusing glow of fluid. The light died out gradually, but the discharge disappeared even more slowly. It was not until one of my last dives that I learned that certain grayish bodies which I had been reporting as unlighted fishes were in reality these burnt-out masses of fluid."

Dr. Harvey (1931) has discussed the chemistry of luminescence in *Systellaspis*.

Among the Oplophoridae, luminescence apparently is found in but two genera, *Systellaspis* and *Oplophorus*, where both photophores and luminous glands may be found in the same species, but the possibility can not be entirely ruled out that luminous glands may be found in other genera as well. More observations made directly from living material should be encouraged to increase our knowledge of the number of species which are luminescent. It is also helpful to preserve some of each species in formalin, for photophores which disappear in a few days in alcohol, will be distinct several years later in material put up in formalin. This recommendation is made with some reservation, however, for alcohol is much to be preferred to formalin as a general preservative.

Food of Bathypelagic Caridea: The following remarks on the food of *Acantheephyra purpurea* and *Systellaspis debilis* are based on such incomplete data that they are included here merely in the hope that other workers may be induced to investigate the problem more thoroughly. Miss Jocelyn Crane dissected out the stomachs of a dozen specimens of *Acantheephyra purpurea* and found them usually crammed with well digested food containing a few identifiable animals. Very much the same type of stomach contents were found in a few specimens of *Systellaspis debilis* which I dissected. In all but one or two cases, surprisingly large fragments of at least one blackish fish were found. Also present were various crustaceans ranging from copepods to comparatively large shrimp-like forms several species of pteropods; worms, some of which may have been parasitic; and radiolarians. The most striking point about these stomach contents was the size of the fragments. In some cases one fish apparently took up the entire space within the stomach and it was often so well preserved as to permit its generic determination. Several of the crustaceans could likewise be determined from the available pieces. Apparently, then, the mandibles do not necessarily crush the food into an amorphous mass before it is passed into the stomach.

One can only guess whether these prawns are able to capture their prey alive or whether they are purely scavengers which feed upon dead or dying organisms. It is very possible that much of the material found in the stomachs of these specimens was consumed after the specimens were in the net. When the contents of a net have been dumped into a tank of water immediately after being taken aboard ship, I have observed specimens of

Systellaspis debilis feeding with apparent enthusiasm upon dead fish as well as dead specimens of their own species. The fact that the stomachs of these prawns were usually distended with food when examined may be entirely due to the plentiful meal provided by the contents of the net and one cannot be certain that this food is representative of their normal diet.

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12.

Eastern Pacific Expeditions of the New York Zoological Society. XIX. Actiniaria from the Gulf of California.¹

OSKAR CARLGRÉN

University of Lund, Sweden.

(Text-figures 1-8).

[This is the nineteenth of a series of papers dealing with the collections of the Eastern Pacific Expeditions of the New York Zoological Society made under the direction of William Beebe. The present paper is concerned with specimens taken on the Templeton Crocker Expedition (1936). For data on localities, dates, dredges, etc., refer to *Zoologica*, Vol. XXII, No. 2, pp. 33-46.]

CONTENTS.

	Page
Introduction	211
Family Aliciidae	
<i>Alicia beebei</i> sp. nov.	212
Family Nemanthidae fam. nov.	212
<i>Nemanthus</i> gen. nov.	212
<i>Nemanthus nitidus</i> (Wassilieff).	214
<i>Nemanthus californicus</i> sp. nov.	215
Family Sagartiidae	
<i>Actinothoe californica</i> sp. nov.	217
Species not determined	219

INTRODUCTION.

The Actiniaria from the Templeton Crocker Expedition to Lower Californian waters contained four species, of which three apparently are new to science. Of especial interest is *Nemanthus californicus*, nearly related to *Nemanthus* (*Sagartia*) *nitidus* (Wassil.) from the waters of Japan, both belonging to a new genus and a new family characterized by having curious, acontia-like formations without any nematocysts at the termination of the filaments.

Family Aliciidae.

***Alicia beebei*, sp. nov.**

Diagnosis: Pedal disc, wide, thin, with fairly distinct insertions of the mesenteries. Column in its uppermost part smooth, forming a capitulum,

¹ Contribution No. 598, Department of Tropical Research, New York Zoological Society.

lower parts provided with sessile vesicles crowded at the base, upwards more scattered; at the border to the capitulum the vesicles are pedunculate, each peduncle bearing 2-7 vesicles. Tentacles long and slender, about 96. Mesenteries 96 pairs of perfect mesenteries. Nematocysts of the lower part of the column 12-14 x 2 μ ; those of the vesicles partly 59-72 x about 12 μ , common, macrobasic amastigophors, partly 60-77 x 6-8.5 μ , very numerous, microbasic amastigophors; those of the capitulum 12-17 x (almost) 2-2 μ , common; those of the tentacles partly 43-51 x 5-5, 5 μ common, microbasic amastigophors, partly 13-18 x (about) 2 μ , common; those of the actinopharynx (26)36-41(46) x 4, 5-5 μ , common, microbasic amastigophors, those of the filaments partly 24-29 x over 4 μ , microbasic amastigophors, partly 7.5-10 x about 2, 5 μ , microbasic p - (penicilli-like) mastigophors; the small nematocysts of the column and tentacles probably basitrichs. Spirocysts of the capitulum up to 36 x 6 μ ; those of the tentacles 17 x 2, 5- (about) 41 x 6 μ .

Color in Alcohol: Basal parts of the tentacles yellowish-brown.

Size: Height 2.5 cm., breadth of pedal disc 2 cm., of the oral disc 1.5 cm.; length of the tentacles 3.5 cm., or longer.

Locality: St. 136 D-30, Arena Bank, 23° 27' N. Lat., 109° 24' W. Long., 35 fms., May 1, 1936, 1 specimen.

Family Nemanthidae fam. nov.

Acontiaria with mesogloal sphincter. No acontia proper but acontia-like organs situated at the termination of the filaments and not forming any batteries of nematocysts.

I refer the family for the present to Acontiaria, because it seems to me that it is more closely related to this subtribe than to the Mesomyaria. The diagnosis of the subtribe Acontiaria may be altered in such a way that it encloses also the family proposed above.

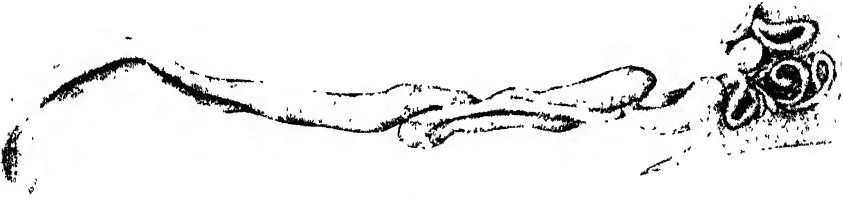
Nemanthus gen. nov.

Nemanthidae with wide pedal disc, smooth column and long tentacles, considerably fewer than the mesenteries at the base. Sphincter mesogloal, well developed. Longitudinal muscles of tentacles and radial muscles of oral disc ectodermal. Actinopharynx with distinct, fairly broad siphonoglyphs, as a rule 2, but possibly varying in connection with asexual reproduction. As a rule 2 pairs of directives; perfect mesenteries at least 6, up to 12 pairs, frequently irregularly arranged, so that one side has more mesenteries than the other, sterile; stronger imperfect mesenteries fertile. Longitudinal muscles of mesenteries not forming distinct pennons; parietobasilar muscles moderately weak or weak. Acontia-like organs, not forming any batteries of nematocysts, present at least on some of the mesenteries. Amastigophors absent in the tissues.

The type of the genus proposed above is *Sagartia nitida* Wassilieff; described from Sagami Bay on the coast of Japan. As the anatomical description given by Wassilieff (1908, p. 31) of the species in several points is imperfect, it was necessary to re-examine the species. It was so much more important as, owing to the imperfect preservation of *N. californicus* described below, I could not describe with certainty some details of its anatomy.

Before discussing the species it seems suitable to describe the curious acontia-like organs so characteristic of the genus. They occurred in all six specimens examined, (4 of *nitidus* and 2 of *californicus*) but always in

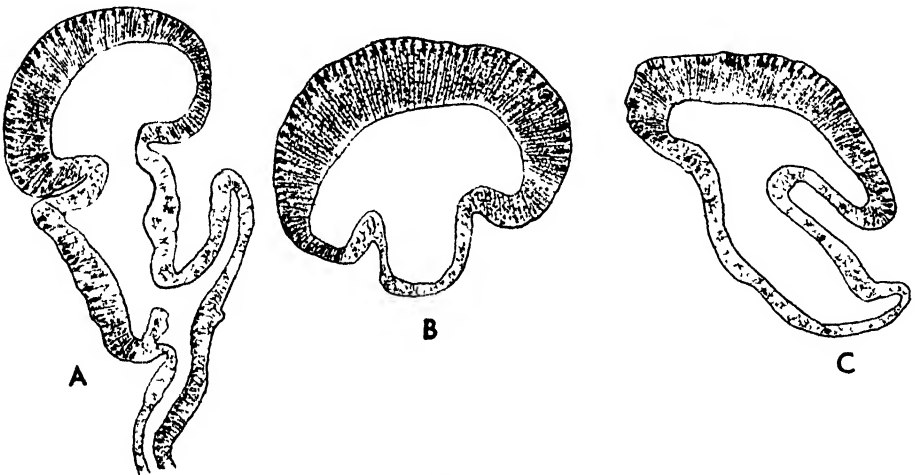
small number and only on some of the mesenteries. Like the acontia they are attached to the mesenteries at the termination of the filaments. They are either short and thick, or longer and sometimes more slender, but always many times thicker than the filaments; in the latter case they were twice found to be squeezed out through the actinopharynx through the contractions of the animals.



Text-figure 1.

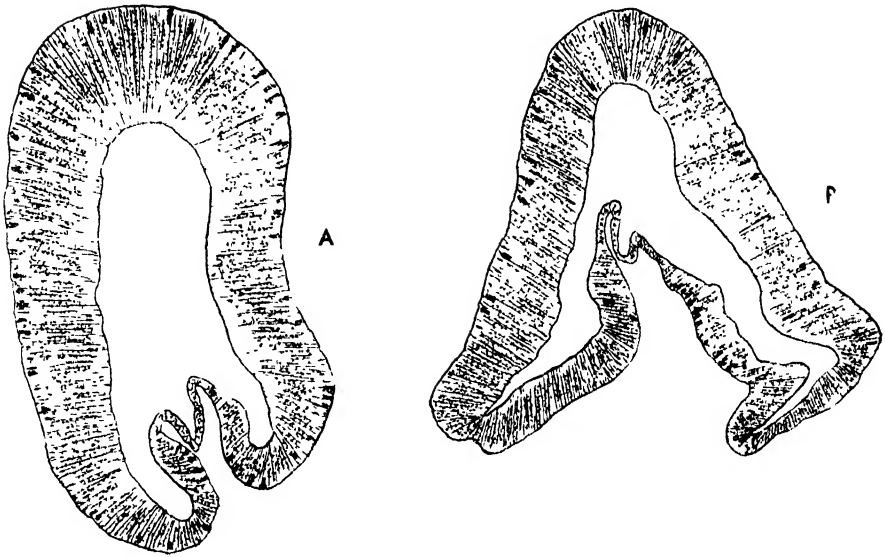
Nemanthus nitidus. Lowest part of mesentery with filaments and acontium-like thread.

Their appearance (Text-fig. 1) is in itself somewhat different from that of an acontium, so it calls for an anatomical examination. I have made slides of two threads, one from *nitidus* and one from *californicus*, and examined several in maceration preparations. Text-figure 1 shows the lowest part of a mesentery with filaments and the acontium-like thread of *nitidus*. Text-figure 2 a, b, c, shows three transverse sections of the same thread, the section on Text-fig. 2 a taken at the insertion of the thread on the mesentery, and Text-fig. 3 a, b, two similar sections of a thread of *californicus*. Thus the cross-sections are seen to recall somewhat that of an acontium. There is an axis of mesogloea, as it seems always thick and surrounded for the most part by a very thick epithelium (ectoderm) and in the part where the mesogloea runs out in a more or less fin-like outgrowth, by flattened endoderm cells. The fin varies very much, from small (Text-fig. 3 a, b) to elongated (Text-fig. 2 c). No muscles are attached to the fin in contradistinction to the conditions of the acontium. The epithelia are not provided with any nematocysts. (True, I have found a few nematocysts



Text-figure 2.

Nemanthus nitidus. Transverse sections of acontium-like thread shown in Text-figure 1.



Text-figure 3.

Nemanthus californicus. Transverse sections of an acontium-like thread.

in some of the maceration preparations, but they belonged probably to the filaments as they agreed in size as well as in types with those. If they occasionally are really present they are at least extraordinarily rare). The question is how to interpret these acontia-like organs which Wassilieff (1908, p. 34) has anticipated to be acontia. They may be degenerated acontia which have lost their nematocysts, or formations *sui generis*, or acontia which have not yet developed their nematocysts. The last supposition is not likely, as the nematocysts appear in the acontia in an early stage of their development (Carlgren, 1934). At present the question must be left unanswered. In certain respects the acontia-like organs recall the acontoids of the Ceriantharia inasmuch as the ectoderm here also consists only of supporting and gland cells.

***Nemanthus nitidus* (Wassilieff).**

Sagartia nitida sp. nov. Wassilieff, 1908, p. 31. pl. I, figs. 18, 19; pl. VIII, figs. 84-87; text-figs. 14-17.

Diagnosis: Pedal disc wide. Column smooth with longitudinal furrows indicating the insertions of the mesenteries. Margin distinct. Sphincter strong, mesogloal, alveolar but here and there more reticular, separated from the muscles of the endoderm and from the ectoderm by a broad mesogloal lamella. Tentacles fairly numerous, up to about 130, not half the number of the mesenteries at the base, conical, the inner ones long, the outer ones considerably shorter. Longitudinal muscles of the tentacles and radial muscles of the oral disc weak. Actinopharynx smooth with indistinct longitudinal furrows and 2 (always?) fairly broad siphonoglyphs. Mesenteries variable in number, up to about 280 at the base, often asymmetrically situated. Pairs of perfect mesenteries 6-12, sterile, the stronger imperfect ones fertile. Two pairs (always?) of directives. Longitudinal muscles of mesenteries weak, forming no distinct retractors, parietobasilar muscles very weak. Acontia-like organs forming no nematocyst batteries,

present on a few mesenteries. Dioecious. According to Wassilieff reproduction by any kind of longitudinal fission. Nematocysts of the column 14-17 x 2.5 μ , basitrichs; those of the tentacles 22-31 x (about) 2.6-3 μ , numerous, probably basitrichs; those of the actinopharynx partly 15.5-24 x (about) 2.5 μ , probably basitrichs, partly 17-18 x 2.6-3 μ , microbasic p-(penicilli-like) mastigophors; those of the filaments partly about 10 x 2.5 μ , partly 13-18 x (about) 2.7-3 μ , microbasic p-mastigophors. Spirocysts of the tentacles 19 x 2.5 - 41 x 5 μ .

Color: According to Wassilieff and Gislén, rose-colored.

Localities: Japan. Sagami. Koaziro, 6 m. T. Gislén, 1930, 2 specimens; Bonin Isl. N.W. of Port Lloyd, 70 fms. S. Block, 1914, 1 specimen; 33° 15' N., 129° 15' E., 45 fms., temp. 73° F. Svenson, 1890, 1 specimen; 33° 5' N., 129° 16' E., 36 fms., temp. 51° F. Svenson, 1890, 3 specimens.

As to the perfect mesenteries, I have examined three specimens, one of which was fertile and had well developed testes in the stronger, imperfect mesenteries. The fertile individual and the single specimen from Bonin Island had 12 pairs of perfect mesenteries, two of which were directives, symmetrically arranged. Both showed the same arrangement of the perfect pairs, 4 pairs on the one side of the directive plane, 6 on the other; the third specimen had only 6 pairs of perfect mesenteries, symmetrically situated. The last specimen had 90 tentacles but about 275 mesenteries at the base, another specimen 136 tentacles and about 280 mesenteries at the pedal disc.

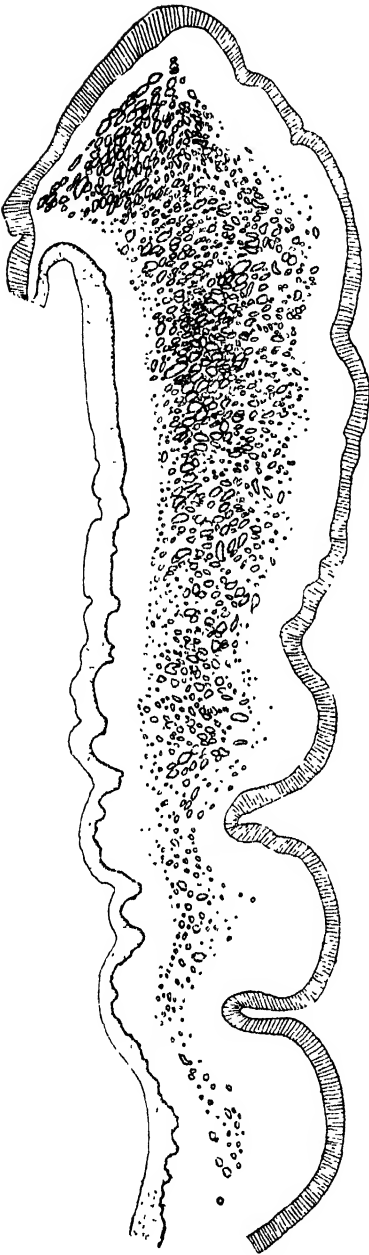
As Wassilieff's figure of the sphincter is very schematic, I give here a more detailed figure of it (Text-fig. 4).

***Nemanthus californicus* sp. nov.**

Diagnosis: Pedal disc wide. Column smooth with more or less distinct, longitudinal furrows. Sphincter strong, in its uppermost part occupying almost the whole breadth of the mesogloea and here reticular, with tendency to transverse stratification on its external side, gradually diminishing in breadth downwards, in its lower part alveolar. Tentacles in number up to about 124, long, conical, the inner ones about twice as long as the outer ones. Longitudinal muscles of tentacles ectodermal, weak; radial muscles of oral disc ectodermal, weak at the insertions of the mesenteries, thickened between them, the folds delicate but not much branched. Oral disc with deep radial furrows at the insertions of mesenteries. Actinopharynx with 2 rather deep siphonoglyphs. Mesenteries at the base up to about twice as numerous as the tentacles. Pairs of perfect mesenteries 8 or more. Two pairs (always?) of directives. Longitudinal muscles of mesenteries forming low folds and uniformly distributed over almost the whole surface of the mesenteries. Parietobasilar muscles not situated on an outgrowth of the mesogloea, reaching upward for some distance, their folds sometimes tall but delicate. Acontia-like organs and probably also reproduction as in *N. nitidus*. Dioecious. Nematocysts of the column 14-19 x 2.5 μ , basitrichs; those of the tentacles 23-29 x 2.5 (about) 3 μ , rod-like, probably basitrichs; those of the actinopharynx partly 17-24 x 2-2.5 μ rod-like, fairly common, partly 18 x 3 μ microbasic p-mastigophors, rare; those of the filaments partly 14-18 x 2.5-3.5 μ microbasic p-mastigophores, partly 8.5-12 x 1-1.5 μ probably basitrichs. Spirocysts of the tentacles 22 x (about) 2.5-43 x 5 μ .

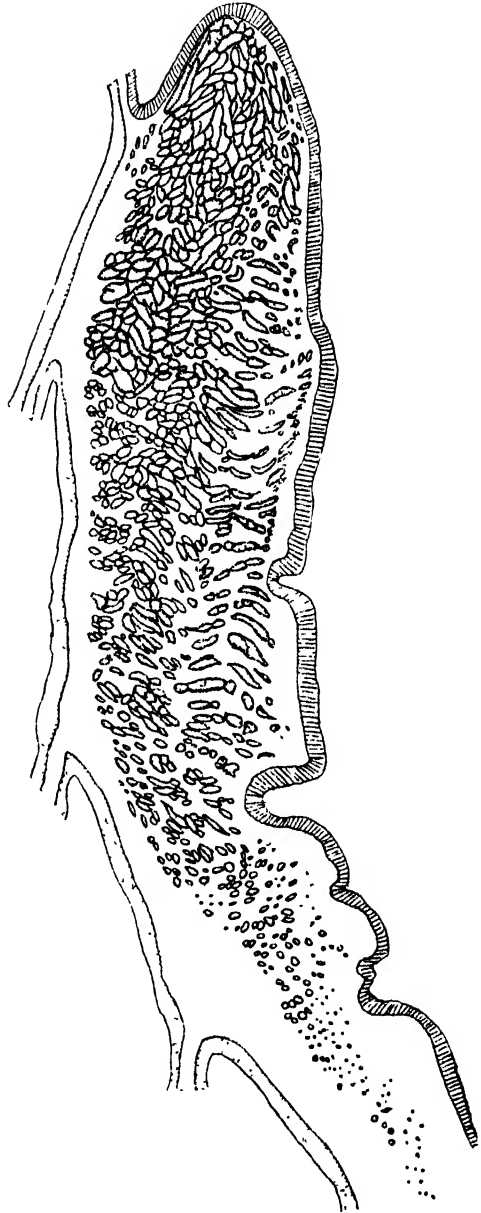
Color in Alcohol: Column with numerous, close, greenish-gray spots distributed over the whole surface.

Size: Largest specimen, average height about 1 cm., breadth about 1.5 cm., (pedal disc broader); length of the inner tentacles up to 1.5 cm., of the outer ones about 0.7 cm.



Text-figure 4.

Nemanthus nitidus. Section of sphincter.



Text-figure 5.

Nemanthus californicus. Section of sphincter.

Locality: St. 136 D-1, Arena Bank, 23° 29' N. Lat., 109° 25' W. Long., 45 fms., April 3, 1936, several specimens. (No. 36171). Some individuals were attached to the stalk of an octocoral.

Text-figure 5 shows a section of the sphincter. Two individuals examined had 8 pairs of perfect mesenteries, a third sectioned had at least 8, probably a few more. It was, however, wrinkled and not so well preserved that I was able to count their exact number. The largest example had about 124 tentacles and 196 mesenteries at the base, another had 112 tentacles and about twice as many mesenteries at the base. The perfect mesenteries were apparently sterile and the development of the generative organs is probably limited to the stronger imperfect mesenteries. A sectioned specimen was a female with numerous, small ova. As with *N. nitidus* the individuals of the present species live together in colonies, sometimes so closely packed that the borders of the pedal disc touch each other intimately. Wassilieff has described longitudinal fission in *nitidus*—perhaps it would be more adequate to speak of budding. Probably asexual reproduction occurs also in *californicus*, since I have found a small bud at the base of one specimen.

Remarks: The species is closely related to *nitidus* but the color is different, the muscles of the oral disc and the mesenteries are stronger, the sphincter stronger and more reticular in *californicus*, etc.

Family Sagartiidae.

Actinothoe californica sp. nov.

Diagnosis: Pedal disc broad, column smooth, cinclides?, margin distinct. Sphincter strong, alveolar, with tendency to be reticulated, occupying in its upper part the whole breadth of the mesogloea, diminishing downwards, and separated from the circular muscles of the column by a fairly thin lamella. Tentacles about 192. Longitudinal muscles of tentacles and radial muscles of oral disc ectodermal. Two distinct siphonoglyphs. Probably not more mesenteries than tentacles. Two pairs of directives. At least 12 pairs of perfect mesenteries. Retractors of the older mesenteries strong, fairly concentrated with tall folds. Parietobasilar muscles apparently weak. Nematocysts of the column partly $17-34 \times 3.5-5.5 \mu$, partly $12-17 \times 1.5-2 \mu$, basitrichs; those of the tentacles partly $21-34 \times 2.5-3 \mu$, rod-like, partly $21-22 \times$ (about) 4μ , those of the actinopharynx $24-29 \times$ (about) 2.5μ ; those of the acontia partly $48-53 \times$ (about) 6μ ; microbasic amastigophors, partly $19-28 \times 2-2.5 \mu$, basitrichs; spirocysts of the tentacles $15-29 \times 2.5-4.5 \mu$.

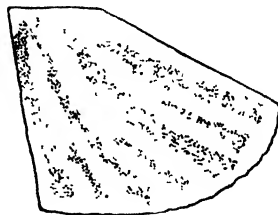
Color in Alcohol: Column with irregular red-brown spots arranged at least in its proximal part in distinct longitudinal rows about as in *A. undata* var. *anguicomma* and *lacerata*. (see Stephenson, 1935).

Size: Largest, strongly contracted example; height 1.5 cm., pedal disc 2.5×2 cm.

Locality: Sta. 142 D-3, Santa Inez Bay, $27^{\circ} 04' N.$ Lat., $111^{\circ} 54' W.$ Long., 40 fms., April 11, 1936. (No. 36,253). 2 specimens on *Murex recurvirostris*, one shell inhabited by a pagurid.

Text-figure 6.

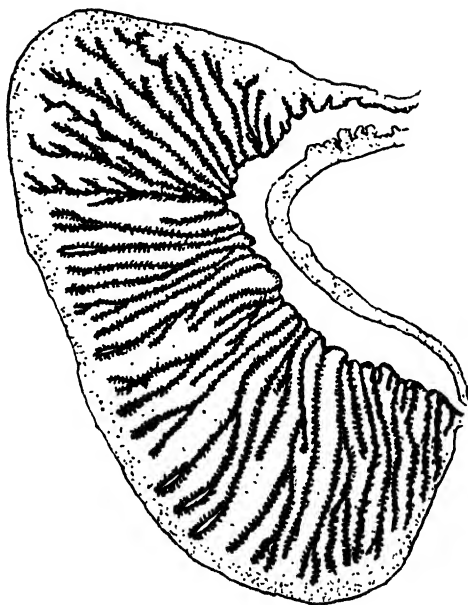
Actinothoe californica. Lower part of column, showing arrangement of spots.



Text-figure 6 shows the arrangement of the spots in the lower part of the column, Text-fig. 7 a section of the upper half of the sphincter and Text-



Text-figure 7.
Actinothoe californica. Section of upper
half of sphincter.



Text-figure 8.
Actinothoe californica. Re-
tractor of a mesentery.

fig. 8 a retractor of a perfect mesentery. Because the pedal disc was extended over the spines of the shells and the body so strongly contracted that the summits of the contracted tentacles almost reached the pedal disc, and the preservation of the individual furthermore was not too perfect, the examination of the specimen was difficult and some observations uncertain. The examined example was a male, but the distribution of the gonads was impossible to decide. As to the broader nematocysts of the column, the shorter ones (about 17-18 μ) were certainly microbasic amastigophors—the capsules were often exploded and the “hampe” somewhat longer than the capsule; the longer ones were probably similar. (They were usually exploded but with the “hampe” torn to pieces, but as I have seen the apex of the “hampe” and it was not provided with a thread, I think that they all were amastigophors though somewhat different in their structures).

The rod-like nematocysts of the tentacles were not examined, the broader being exploded but with the “hampe” damaged, wherefore I cannot decide their category. Probably they were microbasic amastigophors.

Besides the species described above, a fourth species has been taken by the expedition on Gorda Bank, 23° 06' N. Lat. and 109° 25' W. Long., at a depth of 50 fathoms. Two small individuals, both attached to the stem of an octocoral, were present in the collection. One specimen had 72 tentacles and about 136 mesenteries at the base disc, the other about 80 tentacles and about 170 mesenteries at the base. In one individual 10 mesenteries were perfect. The sphincter was strong and mesogloeal-alveolar; the longitudinal muscles of the tentacles were ectodermal. I have made maceration preparations of the tissues in order to examine the nematocysts, but, in spite of careful examination I have not found any nematocysts which could be supposed to belong to acontia. The general appearance of the animals and the characters enumerated here, apart from the absence (?) of acontia, recall those of the genus *Amphianthus*, but as the individuals also were sterile, I have preferred not to name the species.

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13.

Morphological and Embryological Studies on Two Species of Marine Catfish, *Bagre marinus* and *Galeichthys felis*.

DANIEL MERRIMAN

Osborn Zoological Laboratory, Yale University.

(Plates I-V; Text-figures 1-9).

INTRODUCTION.

The material presented in this paper is based on a large number of preserved eggs, young, and adults, of the gaff-topsail catfish, *Bagre marinus*, and the silver or sea catfish, *Galeichthys¹ felis*. The collection of these specimens was made by Mr. M. B. Bishop of the Peabody Museum, Yale University, during 1938 and 1939, while working on a cooperative study of the tarpon at the field laboratory of the New York Aquarium at Palmetto Key, Florida. The entire collection was then put at the author's disposal through the generosity of Dr. C. M. Breder, Jr., Acting Director of the New York Aquarium, and Prof. A. E. Parr, Director of the Peabody Museum.

These two ariids occur commonly along the coasts of the southern Atlantic and Gulf states, but are comparatively rare north of Chesapeake Bay, although the northern limit of their range is Cape Cod (Breder, 1929). *Galeichthys felis* has been taken as far south as the Yucatan Peninsula (Hubbs, 1936), and *Bagre marinus* in Panama (Breder, *loc. cit.*).

The nomenclature of these two species has been discussed recently in papers by Hubbs (*loc. cit.*) and Lee (1937). Former names for *Galeichthys felis* (Linnaeus) include *Galeichthys milberti*, *Hexanematichthys felis*, *Arius milberti*, etc.; among those for *Bagre marinus* (Mitchell) are *Felichthys felis* and *marinus*, and *Ailurichthys* (emended to *Ælurichthys*) *felis* and *marinus*. Hubbs (*loc. cit.*) has also pointed out that Regan's (1907) *Galeichthys guentheri* is not separable from *G. felis*.

Both of these species are particularly interesting from a number of points of view. Thus it is well known that their eggs are among the largest found in the teleosts, averaging 14-19 mm. in diameter before fertilization and during the early stages of development. Furthermore, these catfish exhibit the phenomenon of oral gestation (Smith, 1907; Gudger, 1916 and 1918; and Lee, 1931 and 1937), the males picking up the eggs shortly after fertilization and carrying them in their highly modified mouths through the entire period of development up to the nearly complete absorption of the yolk-sac. Another interesting point about these species is the fact that both of them exhibit sexually dimorphic characters in the pelvic fins; the extraordinary hook-like protuberance on the adaxial surface of the pelvic fin in *Galeichthys felis* females has been described by Lee (*loc. cit.*) and Gowanloch (1933). The osteology of these forms is also of considerable

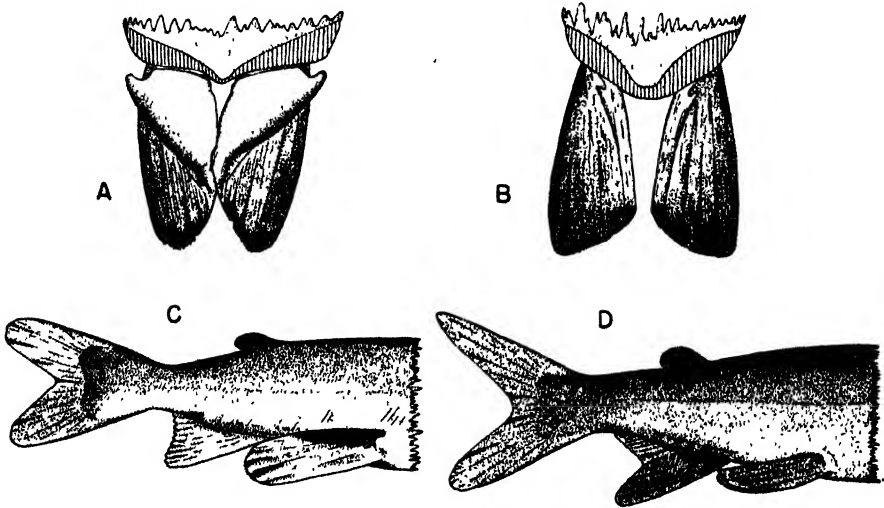
¹ The word *Galeichthys* comes from γαλῆ, weasel, and ἰχθύς, fish (Jordan & Evermann, 1896).

importance because it illustrates the high degree of specialization so characteristic of the Nematognathi. Finally, the inner ears of *G. felis* and *B. marinus* are interesting because they show important structural modifications not found in other groups of fishes. Although most of these points have received some attention from a number of authors, many interesting details have been neglected. This paper takes up various morphological and embryological aspects of these two species, and treats them under the following headings: External Anatomy, Morphology of the Alimentary Tracts and the Feeding Habits, Osteology, Anatomy of the Inner Ear, and Embryology.

EXTERNAL ANATOMY.

The external characters of *Galeichthys felis* and *Bagre marinus* which may be used in distinguishing these two species have been adequately described by many authors, among them Jordan & Evermann (1896), Smith (1907), and Breder (1929). A character which seems, however, to have been generally overlooked is the posterior margin of the anal fin, which in *B. marinus* has a prominent V-shaped indentation and in *G. felis* a comparatively straight border (Text-fig. 1, C and D). This does not show in the illustrations in Jordan & Evermann (1896) and Smith (1907), but Meek & Hildebrand (1923) describe the anal fin in members of the genus *Felichthys* as being "more or less emarginate." Another character which should be used with care is the description of the maxillary barbels as being flat and ribbon-like in *B. marinus*, as opposed to the condition in *G. felis* where the maxillary barbels are said to be "circular" in section. While it is true that these barbels are flatter and more ribbon-like in *B. marinus*, those of *G. felis* are distinctly flat over the greater part of their length, and only approach an oval condition in section at their extreme bases.

The modifications of the pelvic fins in adult female *Galeichthys felis* have been described and pictured in some detail by Lee (1937). The fleshy,



Text-figure 1.

A. The adaxial surface of the pelvic fins of a mature female *Galeichthys felis*, to show the fleshy protuberances which develop in the breeding season. B. The same view of the pelvic fins of a mature male *G. felis*. C and D. Lateral views of the posterior parts of the bodies of *G. felis* and *Bagre marinus* respectively.

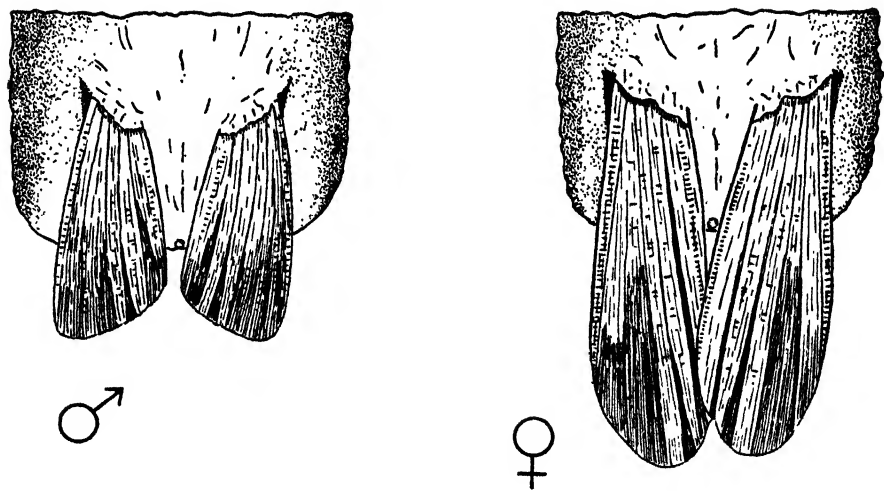
hook-like protuberances on the adaxial surface of the pelvic fins of a female nearing full maturity are shown in Text-fig. 1, A. As noted by Beeson (Lee, *loc. cit.*) this striking pelvic modification of the females becomes larger and more pronounced as the spawning season approaches, and then degenerates after spawning to a relatively inconspicuous affair. At the height of maturity these fleshy protuberances develop to such an extent that the greater part of each pelvic fin is forced into a more or less vertical plane. What is normally the adaxial (dorsal) surface is now turned outwards and is lateral in position, and the original abaxial (ventral) surface is turned inwards and is medial in position (Text-fig. 1, C). The pelvic fins of the females are thus forced into a trough-like structure at the time the eggs are extruded. There is some question as to the exact significance of these changes during the breeding season (Breder, 1935, and Hardenberg, 1935), and as to the uses which this modification might serve. In *Arius maculatus*, an East Indian form which also practices oral gestation, Hardenberg has described a similar development on the female's pelvic fins, and says, "This is a sexual character, which has something to do with spawning and mating. It is clear that the male is attached by these hooks and the fertilization of the eggs takes place perhaps inside the body of the female or more probably outside the body just at the moment when they leave the genital opening." Lee (*loc. cit.*) points out that, "In all probability this modification is widespread through the family, though not of universal occurrence, for Gudger failed to note the structure in *Bagre marinus* and Hubbs found it undeveloped in *Arius aqua-dulce* (as reported by Breder)." This author also has found no similar modification in *Bagre marinus* in his examination of numerous specimens, thus substantiating Gudger.

Lee (*loc. cit.*) says, "No such modification of the pelvic fin has been found in the male, although in egg-carrying males the fin shows a white, almost ridge-like area . . . corresponding in position to the modification in gravid females. The significance of the ridge, if indeed it has any, is not understood; it is perhaps only a rudiment of a structure proper to the other sex." The figure accompanying this statement shows a vague area on the pelvic fin of a gestating male.

In the majority of male *Galeichthys felis* examined in the present work no modification was apparent, but in more than one-third of these male specimens there was a definite structure on the adaxial surface of the pelvic fins. Sometimes this modification was indistinct as indicated in Lee's figure, but at other times it was more conspicuous as shown in Text-fig. 1, B, where it is clearly seen to be a hook-like development not widely different from the condition found in immature and non-spawning females. Furthermore, this modification was found not to be confined to the gestating males.²

Lee (*loc. cit.*) has noted the fact that the pelvic fins of mature female *Galeichthys felis* are considerably larger, in proportion to the length of the fish, than in mature males of the same species. The author finds that this also holds true for the pelvic fins of *Bagre marinus*. This marked sexual dimorphism is shown in Text-fig. 2, where the pelvic fins of two gaff-topsail catfish of the same size are drawn from the abaxial surface. It is apparent that the fins of the male are not only much smaller than those of the female, but that they are also quite different in shape. Thus the greatest length of the male pelvics is on the outside of the fin—near its lateral margin. Also the posterior edge of the fin in males is relatively straight and slants obliquely inward (toward the medial margin, which has the shortest fin rays). By contrast, the female pelvic fins have their greatest length near the region of the middle fin rays. Furthermore, the posterior margins of the pelvics in females of this species are rounded in contour—

² The gonads of some of these male *Galeichthys felis* were sectioned to avoid any possibility of an error in sex determination—in other words, of their having been immature females.



Text-figure 2.

Abaxial views of the pelvic fins of male and female specimens of *Bagre marinus* of the same size. Note the typical sexually dimorphic characters.

not straight as in the males. This is obviously because the lateral and medial fin rays are shorter than those in the middle of the fin, thus making the posterior margin semi-circular in shape. Table 1 shows measurements on the pelvic fins of ten males and ten females of about the same size. The lengths of the fins were taken from the point marked by the junction of the lateral margin with the base, to the tip of the longest ray. The widths of the pelvics were measured from a point marked by the junction of the medial margin with the base, to the lateral margin in a line at right angles to the plane of the fin. The results of these measurements are shown at the bottom of Table 1, where it will be seen that the average lengths of the pelvic fins of males and females of the same standard lengths are 4.4 and 6.4 cm. respectively; the average widths are 1.2 and 1.4 cm. respectively.

TABLE 1.

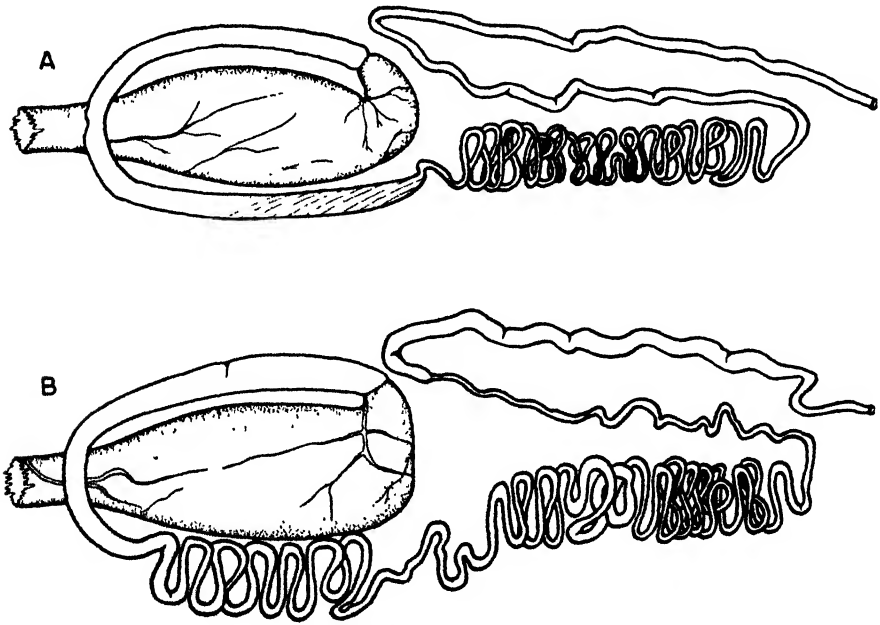
Comparative Lengths and Widths of Pelvic Fins of Male and Female *Bagre marinus*.

Standard length of fish (cm.)	Males		Standard length of fish (cm.)	Females	
	Length of fin (cm.)	Breadth of fin (cm.)		Length of fin (cm.)	Breadth of fin (cm.)
26.0	3.6	1.0	26.5	5.2	1.2
26.5	3.7	1.1	27.0	5.4	1.2
28.5	3.8	1.1	28.5	5.6	1.2
32.0	4.5	1.1	28.5	5.8	1.2
33.0	4.6	1.1	32.0	6.6	1.6
33.0	4.4	1.2	34.5	7.1	1.3
33.5	4.7	1.3	35.0	7.0	1.8
33.5	5.0	1.4	35.5	6.2	1.3
35.0	4.8	1.2	36.0	7.8	1.6
39.0	5.3	1.7	37.0	7.2	1.6
Average	32.00 cm.	4.4 cm.	32.05 cm.	6.4 cm.	1.4 cm.

MORPHOLOGY OF THE ALIMENTARY TRACTS AND THE FEEDING HABITS.

The general anatomy of the coelom and its organs is essentially the same in *Galeichthys felis* and *Bagre marinus*, and only minor differences exist. One of these differences is in the parietal peritoneum of the two species. In *Galeichthys felis* the peritoneal lining appears almost grayish, due to minute black pigment spots which are abundant over its otherwise white surface. These pigment spots are more numerous on the dorsal surface of the coelom than they are on the lateral and ventral walls of the body cavity. In *Bagre marinus*, however, there are no corresponding pigment spots, and the peritoneum is a clean, silvery white.

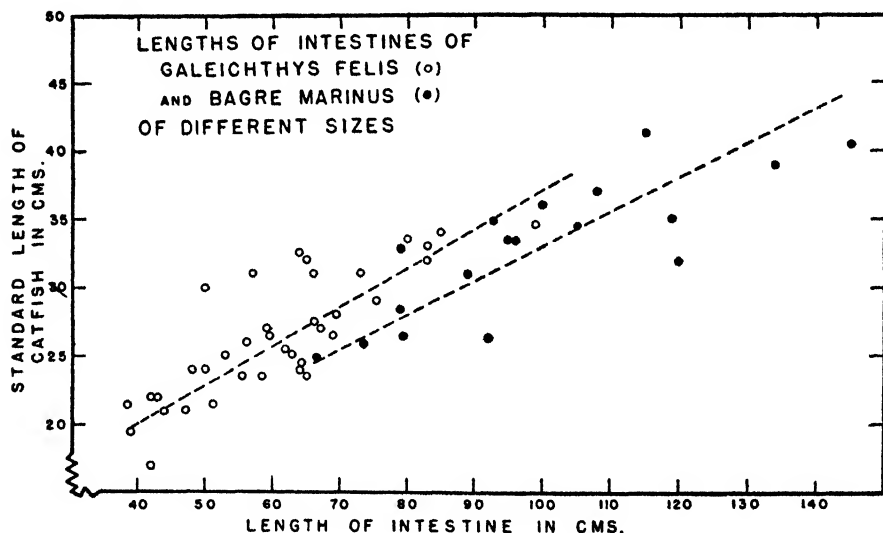
Among the more interesting of the differences between these two species are those found in the morphology of the alimentary tracts. It will be seen in Text-fig. 3 that the fundamental pattern of the gastro-intestinal tracts is the same in both species. Thus, in each type the intestine describes one and a quarter full loops. Yet there are distinct differences within that basic pattern, and these are constant for the species. Thus the stomach in *Galeichthys felis* (Text-fig. 3, A) is typically J-shaped. At its posterior end it makes a sharp bend anteriorly, decreasing in diameter as it does so, and ending in a characteristic constriction marking the pylorus. But the stomach in *Bagre marinus* (Text-fig. 3, B) turns only at right angles to the longitudinal axis at its posterior end and terminates abruptly with the constriction for the pylorus, which is somewhat less distinct in this species. Leaving the pylorus, in *Galeichthys felis* (Text-fig. 3, A), the intestine proceeds anteriorly, slightly lateral to the left side of the stomach. At the anterior end of the stomach it curves to the right and passes ventral to the junction of the oesophagus and the stomach. It then continues to curve sharply and passes posteriorly as a straight tube just lateral to the right side of the stomach. Only by the time that it reaches the posterior end of



Text-figure 3.

Diagrammatic sketches of the gastro-intestinal tracts of *Galeichthys felis* (A) and *Bagre marinus* (B)—ventral aspect.

the stomach does it suddenly become much smaller in diameter. Almost immediately it also takes on a highly convoluted form. These convolutions continue posteriorly nearly to the end of the coelom, where the intestine again turns anteriorly, simultaneously losing most of its convolutions. The intestine then runs to a point close to the pylorus, makes another sharp turn posteriorly and continues back to the anus without any section of it being highly convoluted. The intestinal pattern of *Bagre marinus* (Text-fig. 3, B), although fundamentally the same, differs strikingly in the point at which the convolutions first begin. Here they *start* just after the intestine curves under the junction of the oesophagus and stomach; in other words, the intestine does not continue as a straight tube so far posteriorly. Also there is no sudden decrease in the diameter of the intestine at the point where the convolutions first occur; instead the diameter decreases gradually. The intestine maintains its highly convoluted form to the posterior end of the coelom. It then curves abruptly and runs anteriorly as far as the level of the posterior end of the stomach, bends sharply on itself again and continues posteriorly to the anus; this latter part of the intestine has only minor convolutions.



Text-figure 4.

Graph of the lengths of the intestines of *Galeichthys felis* and *Bagre marinus* of different sizes, to show the proportionately longer intestine of *B. marinus*.

Since the intestine of *Bagre marinus* is convoluted over a greater part of its length than that of *Galeichthys felis*, it is a reasonable expectation that it would be proportionately longer. That this is true is shown by Text-fig. 4, where the lengths of the intestines of both species are plotted against the standard lengths of the fish. It is clearly evident that the length of the intestine in *Bagre marinus* is longer in proportion to the size of the fish than in *Galeichthys felis*. Thus in two individuals 30 cm. in standard length, the intestine would average 75 cm. in *G. felis* and 88 cm. in *B. marinus*. This difference is fairly constant, although it is apparent from the scatter of points on the graph that there is considerable variation and not infrequently an overlap between the two species. However, using Tippet's (1931) method for analysis of small samples, p is less than .001—in other words, the chances are less than 1 in 1,000 that the difference is not significant.

Stomach content analyses show that there is no essential difference in the diets of these two species. Both forms are completely omnivorous. Algae and various kinds of sea grasses are not infrequently eaten by them. Among the invertebrates, coelenterates (sea anemones), holothurians, gastropods, polychaets, and crustacea (isopods, and various decapods such as shrimps, spider crabs—*Libinia* sp., swimming crabs—*Callinectes sapidus* and *Ovalipes ocellatus*, etc.) are all eaten by these species. Teleost fishes also form a common item of their diet; among those which could be identified were: thread herring (*Opisthonema oglinum*), the slender sea robin (*Prionotus scitulus*), various poeciliids, haemulids, sparids and lutianids. There is no assurance, however, that these fishes were taken alive, and there is good reason to believe that many of them were eaten after being thrown back into the water by net fishermen. Both of these catfishes are scavengers and will apparently gather quickly in any place where refuse is thrown overboard. This is shown by the fact that large cycloid and ctenoid scales, which came from fishes that were much too large to be eaten by either of these species, were commonly found among the stomach contents, thus indicating that the catfishes had probably gathered near a boat or dock where fishes were being cleaned for market. The best example of their catholic tastes was found in the examination of the stomach of a single individual (*G. felis*); the contents included coffee-grounds, peas, and pieces of carrots, potatoes and meat.

In view of the fact that oral gestation is characteristic of the males of both species, it is of some interest to consider the feeding habits in relation to reproduction. Observations on preserved egg-carrying male *Galeichthys felis* and *Bagre marinus* are in agreement with those of Beeson (Lee, 1937). Aside from catfish eggs (see below), nothing was ever found in the stomachs of individuals practising oral gestation except an amorphous greenish or yellowish material; most of the time the stomachs were completely empty. Quite often, however, the egg-carrying males were found to have one or more eggs in their stomachs. As Lee has pointed out, these were probably swallowed "because of the confusion resulting when the fish are brought up in the trawl." This conclusion is supported by the observations of Lee and the present author—namely, that in most instances, the eggs showed little or no signs of digestion and were (in each individual's stomach) in the same stage of development as those in the mouth. However, in several specimens in the collection that forms the basis for this paper, eggs were discovered in the stomachs in an advanced state of digestion. A number of alternative explanations can be advanced to account for this. First, it is possible that the fish was frightened into swallowing the eggs at some time considerably previous to its eventual capture. Secondly, it is conceivable that the gastric juices had a chance to act on the eggs for some time, since the fish were not always preserved immediately after capture. Both of these possibilities seem unlikely, however; the second alternative is particularly so, since (as noted by Breder, 1935) the whole eggs should be rather resistant and the effects of digestion should be slight in such a short time, and since in the great majority of occasions when eggs were found in the stomach, they showed no effects of the digestive processes. Thirdly, it is possible that the egg-carrying males sometimes eat one or more of their eggs for nourishment during the time occupied by oral gestation. Since the period of incubation is apparently fairly long (see below), and any other means of obtaining food is impossible because the mouth is so full of eggs, this would not seem to be an unreasonable expectation. The possibility of gastric incubation has been fully discussed by Breder (*loc. cit.*), who cites Devincenzi's (1933) article in which "incubation gastrica" is described in the South American ariid, *Tachysurus barbatus* (Lacépède). Breder places a different interpretation on Devincenzi's description most convincingly, despite the latter's interesting account of the high degree of vascularization of the stomach, and is inclined to believe that the eggs were swallowed from

fright at the time of capture. There is certainly no evidence for gastric incubation in *Galeichthys felis* and *Bagre marinus*. The fact that Lee (*loc. cit.*) and the present author have both found large catfish eggs in the stomachs of female *Galeichthys felis* would indicate that such eggs are not an entirely unacceptable item of diet. These eggs are not necessarily confined to this species, for in one instance the author found eggs that were almost certainly from *Bagre marinus*³ in the stomach of a female *Galeichthys felis*.

OSTEOLOGY.

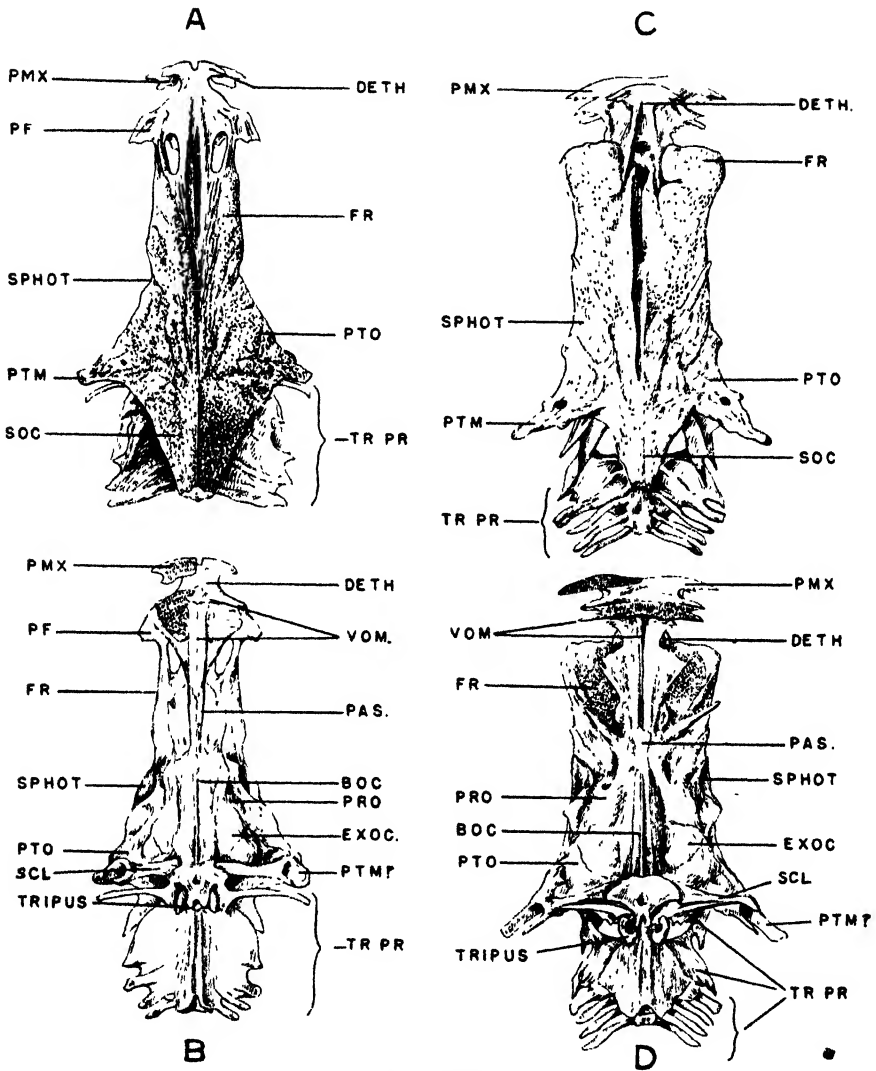
The skulls of *Galeichthys felis* and *Bagre marinus* have received little attention other than that given them by Gudger (1916 and 1925), who pictured them both, but discussed their structure only briefly in relation to the size of the buccal cavity and the likeness of the ventral surface of each to a crucifix and halo⁴ (Text-fig. 5, B and D), and by Regan (1911) in his paper on the classification of the order Ostariophysi.

The present studies show that the high degree of specialization in the skull structure so characteristic of the Nematognathi (Gregory, 1933) is well exemplified by these two species. The bones of the roof of the skull are solidly fused together so as to form the typical cephalic shield (Text-fig. 5, A and C), to which the frontals, sphenotics, pterotics, post-temporals, and supraoccipitals contribute in both forms. Viewed from the dorsal surface, these bones are so well fused that it is extremely difficult to detect the sutures in adults. Here again, the fundamental patterns of the skull structure are much the same, and the main elements contributing to the skull are essentially similar in *Galeichthys felis* and *Bagre marinus*. Yet it is apparent that there are many distinct differences, not only in the shape of the individual bones and the whole cephalic shields, but also in the fontanelles and foramina. For instance, the frontals and supraoccipitals, especially the posterior processes of the latter, are strikingly different in their proportions. And it is clearly evident that the relations of the dermethmoids and premaxillaries are not precisely the same in both species (Text-fig. 5, A and C). The prefrontals are also somewhat different in the two forms, although they have been removed in Text-fig. 5, C and D. In *Bagre marinus* each one is characterized by the presence of a long, relatively thin spine which is directed posteriorly and lies ventral to the lateral edge of the frontal, eventually meeting a corresponding process of the frontal (see Text-fig. 5, D, for this process). In *Galeichthys felis* the spine is much more stout and unites with the lateral anterior portion of the frontal bone; it does not extend under the ventral surface of the lateral edge of the frontal.

In *Galeichthys felis* there is a single median fontanelle which is only partially divided about one-third of the way from its anterior end, and there are two large oval foramina just lateral to the anterior half of the fontanelle. The lateral edge of each foramen is formed by the fusion of the stout posterior spine of the prefrontal with the anterolateral part of the frontal.

³ The eggs of these two species are not easily distinguishable (see below), but *Bagre marinus* spawns considerably in advance of *Galeichthys felis*, and in this instance the time of year this fish was captured and the condition of its own gonads, make it extremely unlikely that the eggs were not those of *B. marinus*.

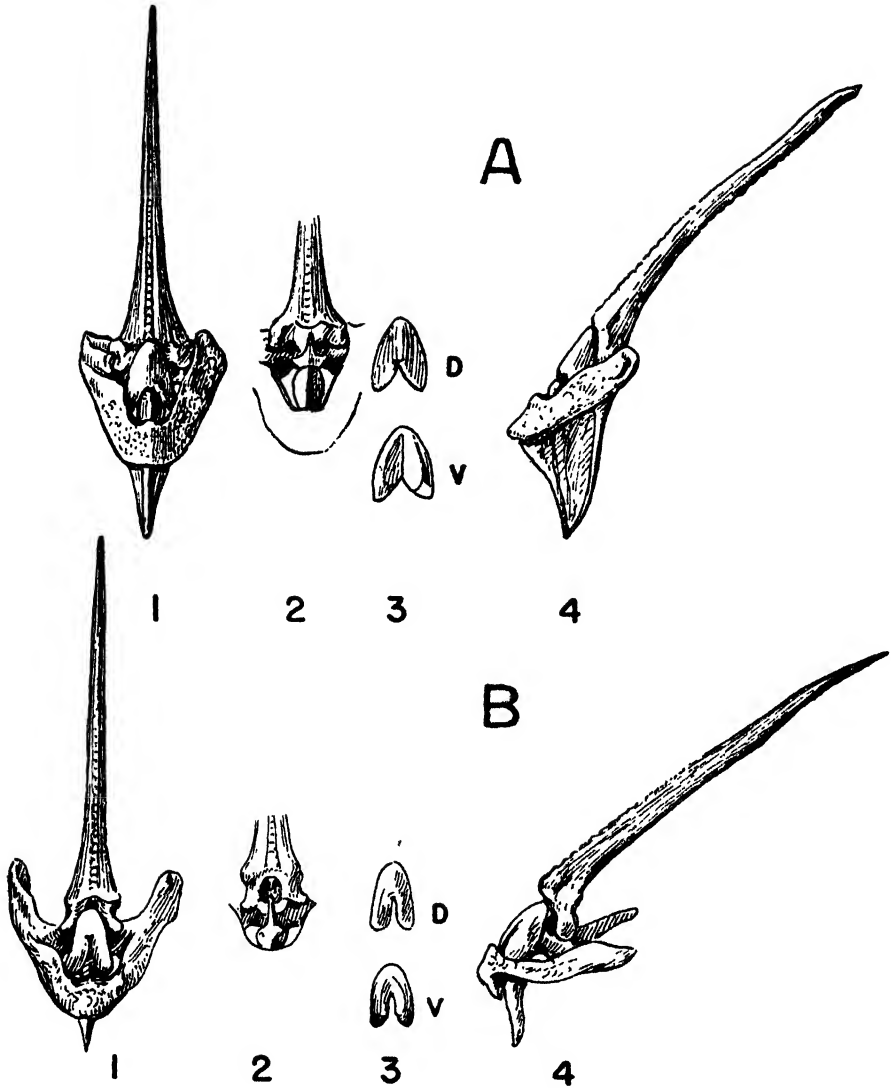
⁴ Norman (1931) discusses this likeness to a crucifix and halo as follows, "Travellers in South America and the West Indies often return with tales of the so-called 'Crucifix-fish,' which is said to be held in great esteem and even veneration by the natives of these parts, who look upon it as a kind of fetish or charm against danger or sickness. These are nothing more than the prepared skeletons of certain Cat-fishes. . . . The skulls of many of these fishes exhibit on their lower surfaces a rough but readily recognizable resemblance to a crucifix, while the small bones known as the Weberian ossicles form a halo. The upper surface of the skull, with its rugose bones, has been described as resembling 'a hooded monk with outstretched arms,' or 'the breastplate of a Roman Soldier'; the dorsal spine is said to represent the spear; and the otoliths, which rattle when the skull is shaken, are the 'dice with which the soldiers cast lots for the garments of our Lord!'" Gregory (1933) in speaking of this resemblance of the under side of the skull to a crucifix, says, "No better example perhaps could be found of a class of fortuitous resemblances between wholly unrelated objects, which the late Professor Bashford Dean called 'Unnatural History Resemblances.'"



Text-figure 5.

Dorsal and ventral views of the skulls of *Galeichthys felis* (A and B) and *Bagre marinus* (C and D).

These fontanelles are probably for the passage of sensory nerves to the snout and barbels. In *Bagre marinus* the median fontanelle is quite different. A small posterior section of it is separated from the main anterior part by a complete fusion of the bony elements in the mid-line (Text-fig. 5, C). The main fontanelle narrows in the middle of its passage forward, but widens into a V-shaped anterior end. Ahead of this terminal portion of the main fontanelle is a single, median, fairly large foramen. The anterior, posterior, and basal walls of this single median foramen in *Bagre marinus* have no perforations, and the only means of entrance into it are through distinct well-rounded apertures on its lateral walls. These apertures lead through canals in the prefrontals and vomer directly to the brain. It may be, therefore, that



*Text-figure 6.

Different views of the nuchal shields of *Galeichthys felis* (A) and *Bagre marinus* (B). 1. Dorsal view of the shield and spine of the dorsal fin. 2. Dorsal view of the articulation of the spine with the shield, the small bone shown separately in 3 having been removed. 3. Dorsal and ventral views of the wedge-shaped bone lying just ahead of the spine of the dorsal fin. See text for description. 4. Lateral view of the shield and its various elements.

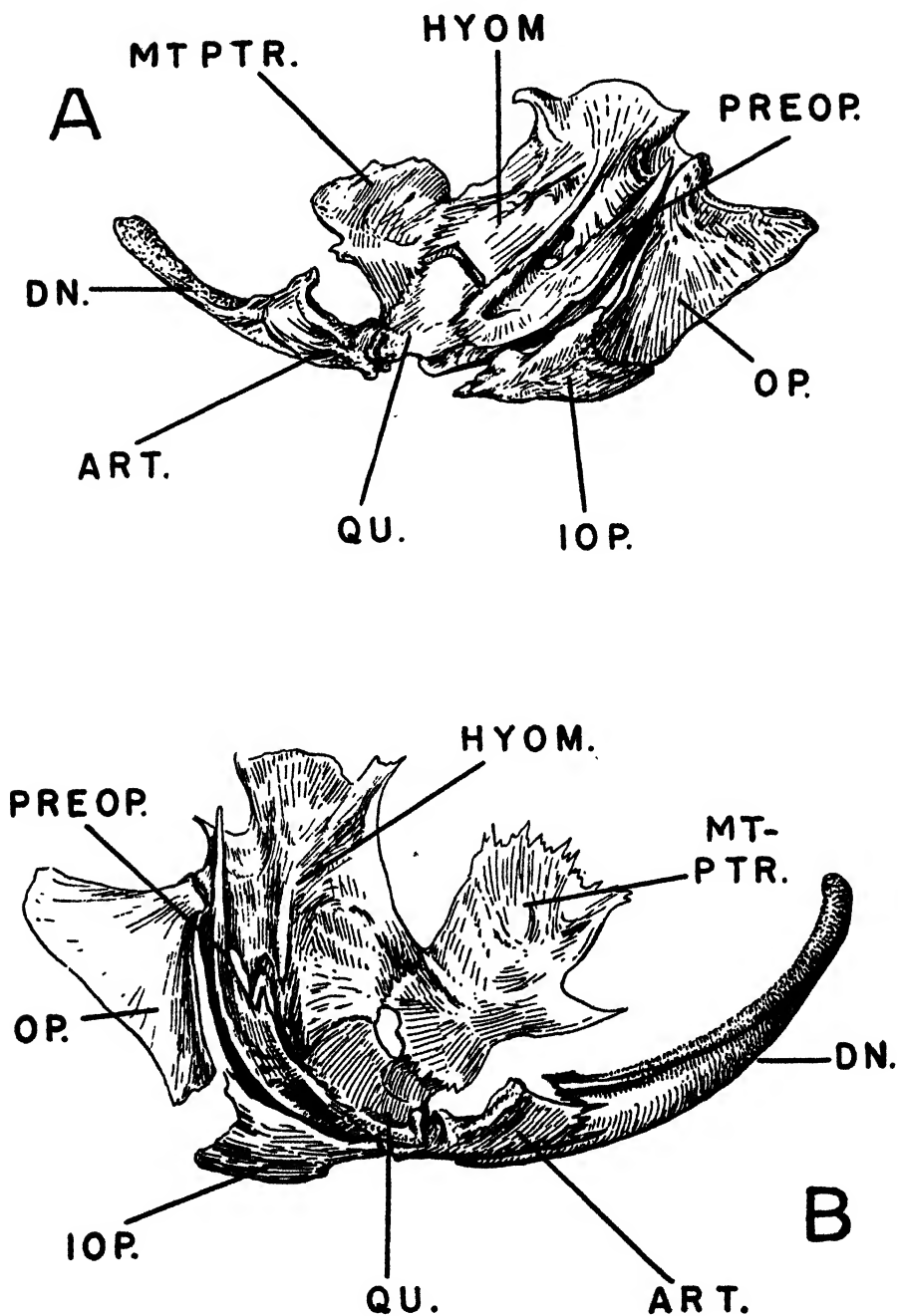
some of the nerves to the snout enter through the lateral walls and reach the surface of the skull via this anterior median foramen. The large, lateral, oval foramina which are so prominent in *Galeichthys felis* are covered over by the forward and lateral expansion of the frontals in *Bagre marinus*, and are only apparent when the skull is viewed from the anterior end. The skull of *Bagre marinus* is also characterized by a prominent foramen on each side

at the junction of the post-temporal and pterotic bones, while the corresponding foramina in *Galeichthys felis* are small and easily overlooked.

Gregory (1933) points out that "the jaws are peculiarly specialized in most siluroids in the reduction of the maxillae to small bones that support the barbels. *Diplomystes*, however, the most primitive catfish, has a well developed maxillary, expanded distally and toothed (Tate Regan, 1929, p. 316)." Both the species under consideration show the reduction of the maxillae clearly. And, as is further characteristic of the catfishes (Starks, 1926), the palatine is rod-like and separate from the pterygoid; however, it retains its attachment to the maxilla and is modified to help control the maxillary barbel. The bones supporting teeth in the roof of the mouth in both species are the premaxillaries and vomers, although as Hubbs (1936) has noted, there may be a wide variation in the vomerine dentition in *Galeichthys felis*. The vomerine and premaxillary teeth were all present in the specimen from which Text-fig. 5, B, was made, but the left half of each series was removed before the skull was drawn. The left premaxillary was removed before the drawing of the ventral surface of the skull of *Bagre marinus* was made (Text-fig. 5, D). It is apparent that the vomerine teeth in *Bagre marinus* form a bar of uniform width across the roof of the mouth. In *Galeichthys felis*, however, the vomerine teeth patches on each side tend to be triangular in shape, the apex of each triangle pointing posteriorly.

There are a number of other interesting points in the study of the ventral aspects of the skulls of these two species (Text-fig. 5, B and D). Among them are the distinct crescentic cavities in the sphenotic bones for the articulation of the curved dorsal edges of the hyomandibulars (Text-fig. 7, A and B). Also, the paired bullae, containing the unusually large utricular otoliths or lapilli (see below), are particularly prominent. Among the bones which contribute to these bullae are the exoccipitals, pterotics, and prootics. The post-temporal bones are of interest for several reasons. First, they are definitely annexed to the skull and form a part of the cephalic shield. Secondly, they apparently (see below) contribute to the formation of a pair of deep sockets for articulation of the sharp prong-like processes of the cleithra of the pectoral girdle (Text-fig. 8). These sockets differ somewhat in the two species, but have the same fundamental construction. Finally, the modifications at the base of the skull are interesting because they are so extreme, although they are essentially comparable to the condition in related forms. The Weberian ossicles (believed to be derived from the ribs and neural arches of the four anterior vertebrae) form a chain of bones on each side, connecting the air-bladder with the perilymph-filled spaces surrounding the inner ear. The tripus, in both species, as in some other Ostariophysi, consists of two parts, a crescentic posterior part, and an anterior section. The anterior vertebrae are highly specialized, possibly, as Gregory (1933) suggests, "... in order to support the massive skull." Regan (1929), describing these vertebrae in this group of fishes, says that the first vertebra forms a disc "rigidly united to the basioccipital and to the second, third, and fourth vertebrae, which are ankylosed to form a complex to which the fifth is rigidly attached and with the parapophyses ankylosed to the centra." The transverse processes in this region where the vertebrae are so highly modified are clearly different in *Galeichthys felis* and *Bagre marinus*, as is shown in Text-fig. 5, but here again the basic patterns are similar.

Just behind the posterior process of the supraoccipital, and in contact with its rear margin, in both species, lies a bony shield. This, according to Gregory (1933), is "... formed by the expansion and coalescence of the bony supports of the first three rays of the dorsal fin." The shields of both species are shown in Text-fig. 6. Together with the posterior process of the supraoccipital, each is known as a nuchal shield. These structures are much alike in the two forms under consideration, and differ only in the proportion and relative sizes of the elements making up the units. One of



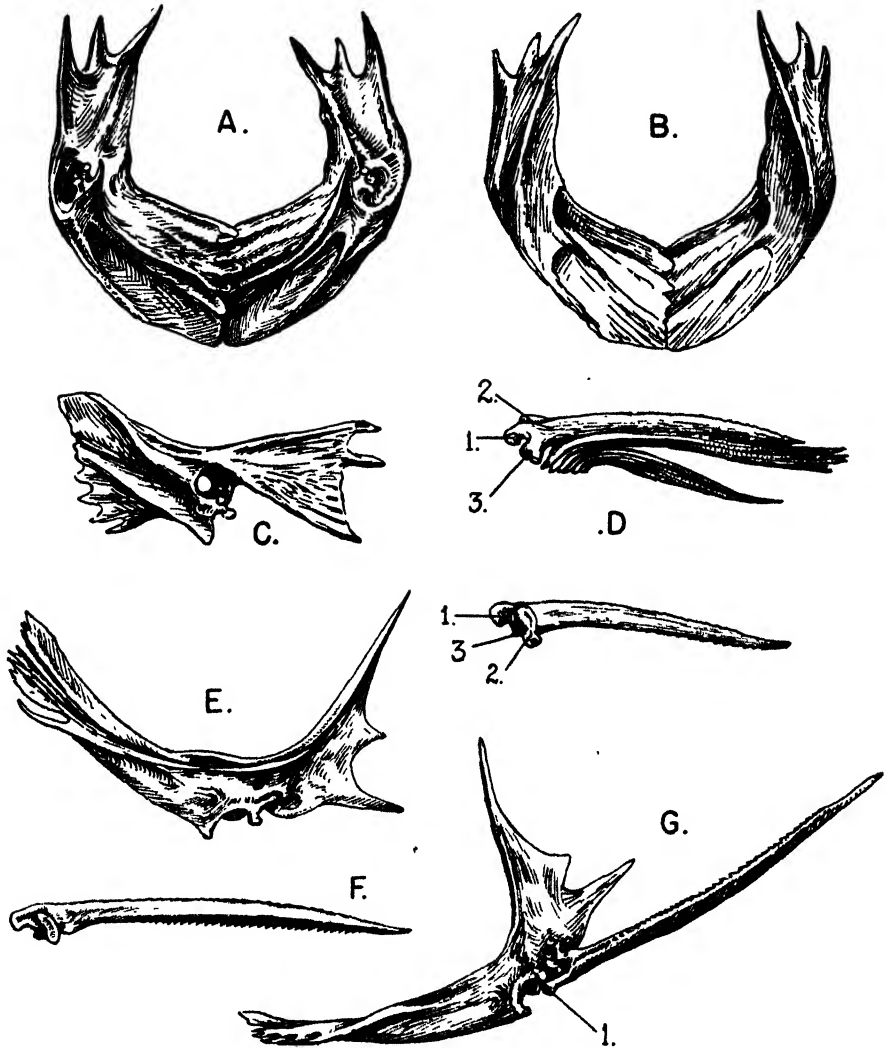
Text-figure 7.

Lateral views of the dentary and opercular series in *Galeichthys felis* (A) and *Bagre marinus* (B).

the more interesting of these elements is the V-shaped, wedge-like bone just anterior to the true spine of the dorsal fin. This is shown in Text-fig. 6, A1 and B1, in its natural position from the dorsal aspect; in Text-fig. 6, A3 and B3, removed from the rest of the elements forming the shield from its dorsal and ventral surfaces; and in Text-fig. 6, A4 and B4, in its normal position from the lateral aspect. This bone appears to be of significance in the articulation of the large spine of the dorsal fin only as a fundamental part of the locking mechanism which keeps the spine erect when it has been advanced to a vertical position. It possibly represents a rudimentary fin ray. Regan's (1911) account of the nuchal shield in siluroids describes this condition and the relations of the spines to the "interneurons" (basalia and radalia).

The lower jaw and opercular series in *Galeichthys felis* and *Bagre marinus* are shown in Text-fig. 7, A and B. Two points are of interest in this part of the skeleton. One is the complete absence of the subopercular bones in both of these forms. This disappearance of the subopercular (coincident with that of the parietals, opisthotic, and symplectic of the skull) is characteristic of the nematognath fishes (Gergory, 1933, and Regan, 1911). The opercle in these forms is in direct contact with the interopercle, and although Text-fig. 7, B, shows a gap between the two, this is simply due to a separation in the process of drying the skeleton, and the natural relationship is as shown in Text-fig. 7, A. The other point to be considered concerns the metapterygoid and the pterygoid bones. As described by Regan (1911) for the Ostariophysi, the metapterygoid has moved forward over the top of the quadrate, and it is relatively large and is connected suturally with the quadrate and hyomandibular. This condition is evident in Text-fig. 7, A and B. In the course of this movement it has taken over the normal position of the pterygoid. In many of the Ostariophysi the pterygoid has disappeared. Gregory (1933) says it has disappeared in all of this group except the Bagridae. This, however, is not actually so, for Regan (1911) has found it in some Ariidae. It is present in both *Galeichthys felis* and *Bagre marinus* (although not shown in Text-fig. 7), and lies dorsal to the metapterygoid and hyomandibular, and somewhat out of the normal relationship of this series. In these two forms the anterior part of the metapterygoid comes exceedingly close to the posterior edge of the palatine. The relationship of the metapterygoid with the surrounding bones is not unlike that shown for "*Amiurus*" by Kindred (1919, Fig. 15).

The pectoral girdles of both *Galeichthys felis* and *Bagre marinus* are shown from different aspects in Text-fig. 8. In both species the main element of the pectoral girdle is the cleithrum, the postcleithrum and the scapula apparently being completely lacking. What Regan (1911) calls the "hypocoracoids" (coracoids), "form an interlocking symphysis behind that of the cleithra." In these two species they are so solidly fused to the cleithra that it is extremely difficult to separate them or to see the sutures. In *Bagre marinus* they are slightly more easy to recognize as distinct entities than in *Galeichthys felis* where the fusion is particularly complete. In both species (Text-fig. 8), the serrated interlocking part of the pectoral symphysis is composed of the "hypocoracoids", and only the extreme anterior portion of the symphysis is formed by the cleithra. The problem of the supracleithrum is somewhat confusing. Regan (1911) describes it as follows for the siluroids: "... the supra-cleithrum . . . is typically forked, the upper limb usually rigidly attached to pterotic and epiotic, the lower to the basioccipital; . . . the distal part, 'stem', of the supra-cleithrum, beyond the fork, is deeply cleft to form a socket for the head of the cleithrum." And for the Ariidae he says, "... supra-cleithrum with stout lower limb united by suture with basioccipital." Text-fig. 5, B and D (SCL), show this relationship much as Regan has described it. Gregory (1933), however, labels the corresponding bone in an *Arius* sp. (Fig. 79) as the post-temporal, in which case the supra-



Text-figure 8.

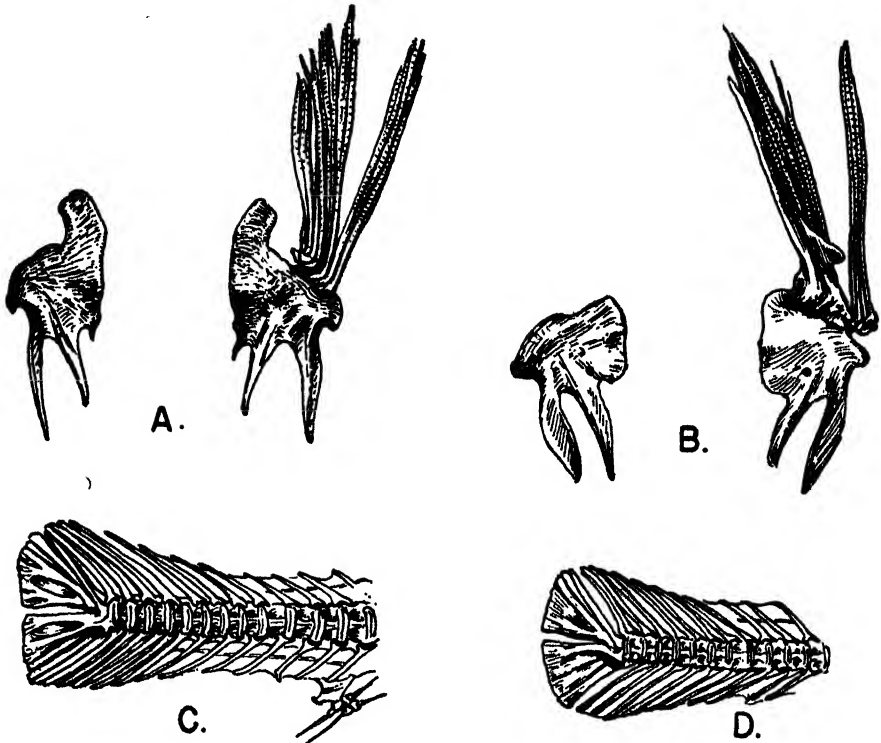
Various views of the pectoral girdle, its elements, and the serrated spine of the pectoral fin of *Galeichthys felis* (A, B, C and D) and of *Bagre marinus* (E, F and G).

cleithrum must be lacking. It seems probable that Regan's interpretation is the more correct, but it also appears that the post-temporal contributes to the socket for the head of the cleithrum. However, because of the high degree of fusion in the bones of the skull in these species, it is difficult to tell in skeletons of adults where the original sutures lay. The dorsal parts of the pectoral girdles in both forms show three, prominent, prong-like processes. The most anterior of these cleithral prongs fit into the deep sockets shown on the base of the skulls in Text-fig. 5, B and D (see above). In Text-fig. 8, A and B, these articulating processes are the ones most medial in position, and in E and G they are the longest of the three prongs.

The articulation of the large serrated pectoral spine and its role as a sound-producing mechanism in both catfishes is of considerable interest. This subject has been discussed by Burkenroad (1931), who worked on *Galeichthys felis* ("milberti") and found that this fish has two methods of sound production. One is by means of a vibration of muscles in the dorsal body wall above the air-bladder, which "would appear to be an 'elastic spring' mechanism essentially similar to that described for other Siluroids by Sørensen (1884)." The other is by means of the highly complicated articulation of the pectoral spine in its socket (Text-fig. 8). There are two aspects of this articulation that deserve attention. One is a defensive locking mechanism when the spine is brought forward to a position at right angles to the longitudinal axis of the body. By means of this mechanism the spine is fixed in place and cannot be pushed back into its normal position unless the anterior (non-serrated) edge of the spine is slightly elevated and the base is simultaneously rotated in a counter-clockwise manner ("counter-clockwise" when the right half of the pectoral girdle is viewed from the lateral aspect). This is due to a small nubbin of bone (Text-fig. 8, D and G, 1) which slips into a socket when the spine is advanced to the defensive position. When the proper muscles exert their action (note the depressions and foramina in the pectoral girdle for the passage of muscles in Text-fig. 8) the tongue-like ridge (Text-fig. 8, D, 2) of the pectoral spine fits into and rotates in a corresponding groove in the socket of the cleithrum. The other aspect of this articulation which deserves attention is the problem of just how and by what part of the base of the spine and its socket the stridulation is effected. This subject is intimately associated with the locking mechanism discussed above, and is reviewed by Burkenroad (1931) as follows:

"Sørensen, in connection with this phenomenon as observed by him in other siluroid species, states that the pectoral spine is fixed in position as a defensive weapon by the friction of an arched crest of its base against the adjacent 'scouring faces' of the articulation. He believes that the 'brake-like' action as the spine is moved to various defensive positions incidentally causes the sounds, which, however, he thinks may have a secondary function in frightening the assailant. Thilo (1896), with whom Sørensen (1896) disagrees, while not mentioning sound production, believes that the arched crest (designated by Sørensen as δ) is a portion of the diarthrosis of the joint. Thilo believes that the essential portion of the defensive locking mechanism is a prop-like projection (*Hemmfortsatz*) of the base of the spine; Sørensen, on the contrary, believes this peg, which he designates as β , to be a part of the diarthrosis. Dufossé (1874), has described the base of the pectoral spine of a siluroid both as a sound-producing and a locking mechanism. The structure and action of the pectoral spine of *Galeichthys milberti* seem to be similar to that of other siluroids described by previous workers."

Burkenroad does not think that (in *Galeichthys*) Sørensen's belief that sound is produced incidentally to the defensive fixation of the spine is correct. He believes, "... that the friction of the crest against the articulating surface ... is adapted ... to sound production." Thilo (*loc. cit.*) is undoubtedly correct in thinking that the arched crest (Text-fig. 8, D, 2) is part of the diarthrosis of the joint. Whether or not the arched crest is the only element that produces the sound by friction against the articulating surface is questionable in these two species. Burkenroad has pointed out that, "Along the lateral contact surface of the crest are a number of fine vertical striations which are thus probably to be considered as stridulatory ridges." These can be seen in Text-fig. 8, D, 2; there is no doubt that they possess the function ascribed to them and are of primary importance in this respect. Yet there is a third process (Text-fig. 8, D, 3) involved in the articulation of the pectoral spine which may possibly play a part in sound production. This process projects posteriorly, and when the spine is partially advanced its medial surface articulates with a small area on the coracoid. In prepared skeletons it is easy to manipulate the spine with only a slight pressure and produce a grating noise from the articulation



Text-figure 9.

A and B. Dorsal views of the elements of the pelvic girdles of *Bagre marinus* (A) and of *Galeichthys felis* (B). C and D. Lateral views of the caudal fin skeleton of *B. marinus* (C) and of *G. felis* (D).

described above. It seems possible, therefore, that this process is at times a sound-producing mechanism, but it certainly does not possess this function to the exclusion of that by the crest. It cannot function in this capacity simultaneously with the arched crest, since when the latter has the proper contact the former does not. It is at best no more than an incidental method of sound production.

The pelvic girdles of *Bagre marinus* and *Galeichthys felis* are shown from the dorsal aspect in Text-fig. 9, A and B. Sheldon (1937) has studied the osteology and myology⁵ of the pelvic girdle of *Hexanematichthys* (*Galeichthys*) *felis*, and Text-fig. 9, B, is shown only for comparison with the pelvic girdle of *Bagre marinus*. The girdles of both species have much the same form. In each the basipterygia unite in the mid-line to form a symphysis, the whole structure being a bilaterally symmetrical unit, the "basal plate" (Sheldon). That of *Galeichthys felis* is slightly thicker and more substantial. Both species have two pairs of elongate anterior processes—an external and an internal pair. Each basipterygium has a single neural foramen in *Galeichthys felis*, while in *Bagre marinus* each has a

⁵ Sheldon (1937) supports the view of Breder (1935) that the hook-like process on the adaxial surface of the pelvic fin in *Galeichthys* (see before) is used as a clasper in the spawning act, on the basis of his findings in the pelvic myology. He notes that various muscles (adductor superficialis, adductor profundus, and abductor profundus) have slips which are clearly differentiated and form almost independent muscles inserting on the most medial rays, which bear the clasper-like processes. This appears to him to be a clear indication of a powerful grasping function for these modified rays.

pair of somewhat less conspicuous foramina. The most prominent difference between the two pectoral girdles is the presence of a pair of broad flat posterior processes on the basipterygia of *Bagre marinus*. These are completely lacking in *Galeichthys felis*. They are situated on the medial part of the posterior margin of the basal plate, and Sheldon (*loc. cit.*) notes that in other nematognath forms they serve as a place of insertion for part of the retractor ischii muscles.

The skeletons of the caudal fins of both species are shown in Text-fig. 9, C and D, from which the large soft caudal fin rays as well as the small hypaxial and epaxial procurent rays have been omitted. Here again the structures are fundamentally the same. In each the elements composing the hypural plate are similar. There are apparently six hypural bones, some of which, however, are well fused. These, of course, vary much in shape, but are not unusual in their distribution or size relationships. The urostyle is a prominent element of both caudal fins, extending almost to the posterior margin of the dorsal angle of the hypural plate. Above the urostyle there is but one dorsal caudal radial in each species. The proximal ends of the first three hypural bones (those most ventrally situated) contribute to the formation of a prominent ridge-like process in each species. This process is undoubtedly for muscle attachment, and is quite comparable to the "hypural spine" described by Merriman (1940) in *Roccus saxatilis*, and figured by Whitehouse (1910) for *Serranus cabrilla* and by Hollister (1937) in *Mugil curema*. The caudal skeletons of these catfish are, in general, characteristic of the less specialized homocercal tail; the long urostyle, and the number and disposition of the hypural bones are indicative of this low form of homocercy, as indicated by Whitehouse (*loc. cit.*).

ANATOMY OF THE INNER EAR.

The anatomy of the inner ear of siluroid fishes has received little attention other than that given it by Neumayer (1908) and de Burlet (1929). De Burlet's paper contains a full account of the auditory organ of "*Amiurus*" (*Ameiurus*) *nebulosus* and other siluroids, and is by far the most extensive discussion of this subject. It does not, however, contain information on any of the Ariidae.

The otoliths of siluroids have been studied by Frost (1925), who has also recorded a utricular otolith resembling those of siluroids from the Upper Jurassic in England (1926). As Gregory (1933) notes, this "is another suggestion of the relative antiquity of the ostariophysal fishes." In North America the fossil siluroids are poorly represented. Among the Ariidae, Cope (1884 and 1891) described seven species belonging to the genus, *Rhineastes*, which he erected for them.⁶ Lynn and Melland (1939) have described an interesting fossil catfish (*Felichthys stauroforus*) from the Maryland Miocene. Not only the skull, but also the structure of the otolith, clearly indicate that this individual is closely related to the two forms that are the subject of this paper.

The inner ears of *Galeichthys felis* and *Bagre marinus* are almost identical in structure. Each has a large rounded utriculus, with its utricular otolith or lapillus, above, and a smaller elongate sacculus, with its saccular otolith or sagitta, below. Each also has the small sac-like outgrowth from the sacculus, the lagena, the forerunner of the spirally twisted cochlea of higher vertebrates; these lagenae each have a characteristic otolith, the

⁶ Lynn & Melland (1939) point out that, "The remains upon which these species are based are extremely fragmentary, consisting of small portions of skull plates, isolated fin-spines and otoliths. Nevertheless, they are sufficiently complete to indicate clearly that the genus belongs among the sea-catfishes so it has been assigned to the family Ariidae by Jordan (1923)." Hay (1929) lists five other species (besides Cope's seven) from North American deposits; these, however, are freshwater forms belonging to the family Ameiuridae.

asteriscus. These chambers with their otoliths and the semi-circular canals are shown in Plate I, A, B; the lapilli and asterisci removed from their respective chambers appear in Plate II, A, B, C, D.

The semi-circular canals are of course connected with the utriculus and are quite normal in relationships and distribution. There are the typical anterior and posterior vertical canals and the horizontal canal in each. The prominent ampullae are located in their usual positions and are clearly visible in Plate I, A, B. Due to the much enlarged utriculus, however, the semi-circular canals lie close to this upper chamber, and do not extend well above it as in other forms. Instead, the utriculus fills the whole space between the canals, and all three of the canals run close to and often touching the surface of the utriculus. The semi-circular canals are not solidly embedded in the bones of the skull, and only small portions of them pass through bone. It is also worth mentioning in passing that the utriculus is covered with a layer of highly pigmented tissue. This melanistic pigmentation is clearly visible in Plate I, A, B, although in A part of this tissue was removed before the photograph was made. The pigmentation is not confined to the utriculus and can be seen both on the ampullae and the semi-circular canals. The sacculus and lagena, by contrast, are unpigmented.

The sacculus and lagena are not unusual except in relation to the large size of the utriculus (see below). They are, however, solidly embedded in bone. The saccular otolith (sagitta) in both species is an elongate and highly brittle affair. Unlike the asteriscus or lapillus, the sagitta crumbles easily. It is irregularly circular in cross-section, narrowing at both ends and rounded at either extremity—in other words, it is roughly cigar-shaped. In adults it is 4-6 mm. in length. The otolith of the sac-like lagena, the asteriscus, from *Bagre marinus* is shown in Plate II, C, D, from the dorsal and ventral surfaces. In both forms it is a thin, disc-like affair, averaging 3-5 mm. in diameter in adults. The spiral appearance of its flat surface shown in Plate II, D, is characteristic of the two catfishes that form the subject of this paper. As can be seen in Plate I, B, the asteriscus lies directly above the sagitta, which runs in an antero-posterior direction, and its flat surfaces form dorsal and ventral sides.

In almost all fishes the sagitta is the largest otolith and the lapillus tends to be small and insignificant, although in some forms the sagitta is small and the asteriscus is relatively large. In *Galeichthys felis* and *Bagre marinus*, however, the utricular otolith or lapillus is much enlarged and dwarfs the sagitta and asteriscus by comparison. The lapilli of these adult catfishes may be as much as 15-16 mm. in diameter. As described by Frost (1925) their "shape is conchoidal and biconvex." Each has a prominent posterior process, and each has characteristic markings that are nearly identical in both forms (Plate II, A, B). Frost (*loc. cit.*) notes that in the Ariidae in general "... the lapillus is much larger, in comparison with the other otoliths, than in other Siluroids except the Plotosidae." In conclusion he states, "In the Ostariophysi the saccular otolith, the sagitta, which is generally the principal otolith in other fishes, is attenuated and diminutive. In the Cyprinoids and *Diplomystes* the asteriscus is the largest otolith, in the Siluroids (except *Diplomystes* and a few South American species) the lapillus. It seems possible that the reduction of the sagitta may be related to the development of the Weberian mechanism, and that the great development of the lapillus or utricular otolith, in the Siluroids, may in muddy waters compensate for the decreased use of the eyes for maintaining equilibrium." This last statement appears to be somewhat debatable, but may well be a partial explanation of the relatively large size of the lapillus by comparison with that of the sagitta. Frost also points out that the interrelationships of the Siluroid families with each other and with the primitive characins are clarified considerably by studies on the otoliths.

EMBRYOLOGY.

Despite the fact that the eggs of *Galeichthys felis* and *Bagre marinus* are among the largest known in the teleost fishes, only a few authors have made any study of the embryology. This is partially because of the difficulty of getting a complete series of developmental stages, owing to the habit of the males in both forms of practicing oral gestation. Both Gudger (1916) and Lee (1937) experienced the greatest difficulty in keeping the eggs alive after removing them from the parent male's mouth. It therefore appears probable that the most feasible way to obtain a complete series is to collect the egg-carrying males in sufficient numbers until all the stages are filled. This necessitates a large collection since the eggs in a single male's mouth are usually all in the same stage of development.

The present studies are confined mainly to the eggs and larvae of *Galeichthys felis*, and are based entirely on preserved specimens. It is apparent from Gudger's (1916 and 1918) figures, however, that the eggs and larvae of *G. felis* are much like those of *B. marinus*. Comparing the small number of eggs of *B. marinus* in the present collection with those of *G. felis*, it is not easy to distinguish between the two forms in early stages. Gudger's (1918) measurements of the eggs of *B. marinus* would indicate that they average a little larger than the eggs of *G. felis*, but there is considerable overlap between the two forms since there is a wide variation in size in each type (see below). Many of the characteristics which serve as a means of distinguishing these catfishes when they become adults, however, are useful in separating the later egg stages of the two forms. Thus the barbels are sufficiently well developed some time before hatching to enable immediate identification, although the removal of the egg shell usually facilitates the necessary observations. The two barbels on the lower jaw of *Bagre marinus* and the four on that of *Galeichthys felis* are differentiated early in development. Also the much longer maxillary barbels and the filaments on the pectoral and dorsal spines in *B. marinus* are apparent well before hatching.

The study of the gonads of a large series of adult and immature specimens of *Galeichthys felis* and *Bagre marinus* varying in size from 17-44 cm. (standard length) has given some interesting information as to the time of spawning, the maturation of the ova, the age of maturity, etc. The individuals on which this study is based were collected in February, March and April, and June, July and August. It is evident from this collection that the main time of spawning for *G. felis* in 1938 on the west coast of Florida was June and July, while *B. marinus* spawned about a month earlier in this locality in that year. This information checks well with the conclusions of Lee (1937) on *Galeichthys felis*, which were based on observations over a number of years in the vicinity of Grand Isle, Louisiana.

The size of the eggs of *G. felis* just before spawning ranges from 12-19 mm. in diameter, the average being from 14-17 mm. Gudger's (1918 and 1919) measurements on the eggs of *B. marinus* show that the average size is 19-20 mm., and that the lower limits of size in this form are comparable to the average size of the eggs of *G. felis*. It should be mentioned, however, that Gudger's measurements were on unpreserved material, by contrast to those in the present study. But the limited number of measurements of the eggs of *B. marinus* which the present collection allowed, indicate that the eggs are usually somewhat larger than those of *G. felis*. The eggs of both forms vary in shape from a somewhat oval or elliptical to a perfectly spherical condition, the latter state, however, being much less common. The measurements given in this paper refer to the longest diameters in every instance. Just after spawning the largest eggs in the ovaries of these two forms average 2-4 mm. in diameter, although there are occasionally eggs up to 6 mm. in diameter. There are, of course, countless eggs of various

sizes below 2 mm. The larger eggs at this time are undoubtedly those which will be spawned the following season. It is of course impossible to obtain much information on the progressive increase in size of the developing eggs without material collected throughout the year. However, studies on a limited number of apparently maturing females of both forms taken in February, March and April, indicate that the increase in size of the eggs at this season is extraordinarily rapid, and that there is relatively little change in egg size from immediately after the time of spawning in the spring and early summer to January and February. In other words, the tremendous increase in bulk of the maturing eggs in both forms is mainly confined to the four or five months immediately preceding spawning; this increase in bulk is therefore not a progressive affair over an eleven or twelve months period, but is mainly concentrated in a much shorter space of time. Thus the largest maturing eggs from the gonads of *Bagre marinus* averaged from 5-8 mm. in diameter in February, about 14 mm. in diameter in March, and 18-19 mm. in diameter in samples taken in April. Similar samples of maturing eggs from the gonads of *Galeichthys felis* indicated that the increase in bulk of the eggs was equally rapid but did not start until a month or more later. In March the eggs were only 4 mm. or a little more in average diameter, but by April they had increased to 7 mm. in most instances, and in one individual the largest eggs were 12-14 mm. in diameter. The somewhat later period of rapid increase in bulk of the maturing eggs of *Galeichthys felis* is undoubtedly correlated with the correspondingly later time of spawning in this form.

The present collection was unfortunately rather limited in the numbers of immature individuals, so that it is impossible to draw many conclusions as to the size at which these two catfishes first become mature. Lee (1937) found one female *Galeichthys felis* only 12.6 cm. in standard length which was gravid. The present author has found a considerable number of female sea catfish up to and occasionally above 20 cm. (standard length) which were either immature or not spawning in that particular season, for their gonads had no eggs larger than 2-4 mm. in diameter immediately before the spawning season, at a time when mature fish possessed many eggs 14 cm. or more in diameter. These were not fish which had spawned in advance of the main lot, since their gonads were firm and full and did not have the typical flaccid, empty appearance characteristic of gonads that have just lost the mature eggs and show empty follicles. It therefore seems probable that there is a considerable variation in the size at which female *Galeichthys felis* first mature; this range is roughly from 12-20 cm., with the majority of individuals maturing for the first time near the upper end of the scale. No information was obtained as to the size at maturity of male *Galeichthys felis*, save from several individuals that were either immature or not spawning that season; these fish were 19 and 20 cm. in standard length respectively. It may therefore be that the males mature when slightly larger than the females. Males above 25 cm. were found to be mature. The collection did not contain any immature *Bagre marinus*, so it is impossible to draw any conclusions as to the length at maturity of this form. The smallest specimen was 26.5 cm. in standard length and was a mature female.

The problem of how many mature eggs are produced each season by the females of these two catfishes is of considerable interest in view of the large size of the eggs. In *Galeichthys felis* the number of mature eggs per gonad usually varies from 10-20, and the total number per fish 20-40. Occasionally a larger number of eggs were found, however; one individual collected just before the spawning season contained 53 mature eggs in its gonads, while another had 64 (39 in one gonad and 25 in the other). The average number of eggs produced each year by *Bagre marinus* is of the same order of magnitude. Evidence that all the mature eggs in one season are not extruded at one time in *Galeichthys felis* is forthcoming from the examina-

tion of gonads from individuals in the present collection. A number of females were found which possessed one gonad in which all the mature eggs had been released and in which empty follicles were plainly evident, but in which the other gonad had a few mature eggs and some empty follicles. Such an individual had certainly spawned once or more already, and in all probability would have spawned again that season and so have rid herself of the few remaining mature eggs, thus indicating that polygamy in this form is apparently not uncommon.

The number of eggs carried in the mouths of the orally gestating males has been treated by Gudger (1918) for *Bagre marinus* and Lee (1937) for *Galeichthys felis*. Gudger found this number to vary from 2 to 55, the average being from 15-30. The largest number of eggs in the mouth of a male *Galeichthys felis* recorded by Lee is 48. The average number is slightly less than that for *Bagre marinus*. In the same manner as indicated by Gudger for *Bagre marinus*, a single female *Galeichthys felis* can apparently produce more eggs than a single male can carry in his mouth, which is added evidence that polygamy is not uncommon among these forms.

The eggs in the mouth of any individual male are usually all in the same stage of development, but, as noted by Lee (1937), there are exceptions. Sometimes there may be several infertile eggs among the developing ones, and rarely one or two eggs that are in a much earlier stage of development than the main lot. Undoubtedly the infertile eggs are picked up with the fertile ones by the male at times. It may also be that if a male does not acquire his full complement of eggs the first time, he will attempt to pick up additional eggs later on. On the other hand, several eggs in an earlier stage than the majority in a male's mouth may simply be cases of retarded development, as suggested by Lee.

As mentioned before, the young remain in the parent male's mouth long after hatching, in many instances up to the time when the yolk sac is completely absorbed. Gudger (1918) believes the entire incubatory period to be 60 to 70 days in *Bagre marinus* near Beaufort, N. C. Evidence from the present collection indicates that the time occupied by oral gestation is somewhat shorter for both *Galeichthys felis* and *Bagre marinus* on the west coast of Florida, and that 6 to 8 weeks is the period there; this estimate, however, is based on an inadequate amount of material (see below). Gudger is convinced that the young *Bagre marinus* actually feed while still in the mouth of the parent male, "... filtering out of the respired sea-water, by means of their closely set gill rakers, minute crustacea to satisfy their hunger." Proof that this supposition is correct not only for *Bagre marinus* but also for *Galeichthys felis* is provided by the dissection of individuals in a late stage of development but still in the parent males' mouths. Stomach content analyses showed that in almost every instance these small fish had been feeding heavily. There is some possibility, of course, that the small fish feed outside the parent male's mouth and subsequently return to it or are picked up again by the male.

The developmental stages of *Galeichthys felis* are shown in Plate II, 1-6, and Plate III. Plate II, 1, shows the whole egg in which the developing embryo is at the earliest stage represented in the entire collection. The egg shell has not been removed (as it has in the succeeding photographs in this figure), and it is possible to see the distinct space between it and the yolk and developing embryo. This perivitelline space is apparently formed at or shortly after the time of fertilization, when the chorion moves out from the yolk which it so closely surrounds before fertilization. Plate II, 2, shows the same stage with the egg shell removed, and the developing embryo is clearly visible on the surface of the yolk. A photograph of a whole mount of this embryo dissected away from the yolk is shown in Plate III, 1. It is obvious that at this stage the eye and lens are clearly differentiated, mesodermal segmentation has progressed a long way, the

somites being evident over the greater part of the entire length of the fish, neuromeres are distinctly visible, the pectoral limb buds are apparent, and the otoliths have formed. The frontal and sagittal sections of embryos of this stage shown in Plate IV, 1, 2, 3, also illustrate these points. It is characteristic of the yolk at this stage to show an irregular trough-shaped indentation of considerable size in the vicinity of the embryo. The embryo usually lies at one end of this indentation, the posterior part of its body being in it, while the anterior end extends out onto the smooth surface of the yolk. This is probably the groove into which the embryo fits so closely at subsequent stages.

It is of some interest to consider why no earlier stages were present in the entire collection despite the large number of eggs which were examined. Gudger (1916) failed to obtain any of the segmentation stages in his studies of *Bagre marinus*, but got a complete series "from invagination to the free swimming young in which the walls of the belly have closed over the diminished yolk sac and have coalesced into a raphe on the median line." In *Galeichthys felis* the absence of any early stages may possibly be accounted for by the following statement by Smith (1907): "Spawning occurs in the summer, the large eggs being first deposited in a sandy depression and subsequently taken into the mouth of one of the parents. . . ." Others have made similar observations (Gudger, 1918), which, if reliable, would account for the lack of early stages in the mouth of any orally gestating male.

The next stage of development in *Galeichthys felis* is shown in its normal relation to the yolk in Plate II, 3, as a whole mount of the embryo dissected away from the yolk in Plate III, 2, and in sagittal section in Plate IV, 4, 5. By this time there has been a considerable advance over the previous stage. The eyes have become particularly prominent, the pectoral limb buds have enlarged considerably, and the "coiling" of the body so characteristic of the later stages has started with the twisting of the caudal end of the embryo to a position where it is at right angles to the longitudinal axis of the body. This coiling in a more advanced state is apparent in Plate II, 4, 5, and Plate III, 3. Here it will be seen that the posterior half of the body has twisted to such an extent that the caudal fin at least touches the head and more usually overlaps it completely. This coiling is neither universally sinistral or dextral; however, it tends to be counter-clockwise in the majority of the specimens examined. It will be noticed that the pigmentation of the dorsal surface of the body becomes increasingly prominent as this coiling stage is more fully developed. The barbels, which serve as a means of distinguishing these two catfishes (see before), are also clearly evident by this time. Furthermore, the prominent utricular otoliths have attained a large size at this stage and the hypural plate has undergone considerable development (see Plate III, 3). Sagittal sections through the anterior part of the body at the coiling stage are shown in Plate V. The parasagittal section in Plate V, 1, shows the well-developed eye with its retina and lens, the characteristic and perfectly normal gill arches, and the large space in the posterior part of the neurocranium that is the site of the more prominent part of the inner ear—namely, the semicircular canals, utricle, and lapillus. The nearly median sagittal section at the same stage (Plate V, 2) indicates, by comparison with sagittal sections of the previous stage, that the main steps in organogenesis have been accomplished during this phase of development. Thus the swim-bladder, with its distinct partitions, the oesophagus and gut with its rugose lining, the beginnings of the convolutions of the gastro-intestinal tract, the kidney, etc., are now clearly evident.

The developing embryo apparently remains in the coiled stage up to the time of hatching. Shortly after hatching the yolk sac is still large, but the larvae are well-developed and most of the fundamental differences

between *Bagre marinus* and *Galeichthys felis* are readily apparent—e.g., see the photograph of the newly hatched *G. felis* in Plate II, 6. The yolk sac is now gradually absorbed, and, as mentioned before, the small fish are regularly found in the parent males' mouths up to and even some time after the complete disappearance of the yolk sac.

Finally some information on the rate of development of *Galeichthys felis* is provided by the following data. The eggs in the earliest stage taken (Plate II, 2, and Plate III, 1) were found in the mouths of males commonly in late July, and in one instance in mid-August in 1938. Those in the succeeding stages of development (Plate II, 3, and Plate III, 2) were taken most frequently in late July and early August, although these too have been collected in mid-August or slightly later. Embryos in the late coiling stage were taken in greatest numbers in mid-August, although it was not uncommon to find individuals which had hatched and even those in which the yolk sac had been completely absorbed by this time. Unfortunately the collection of material stopped shortly after the middle of August, so that it was impossible to draw any conclusions as to how much later oral gestation is carried on. The largest individual taken from the mouth of a parent male at this time was 49.5 mm. in standard length, and many larvae averaging about 40 mm. were collected at that date. The above information indicates that in 1938 on the west coast of Florida, hatching occurred in about a month, and that the larvae were retained in the parents' mouths from 2-4 weeks thereafter.

SUMMARY.

1. The material presented in this paper is based on a large number of preserved eggs, young, and adults, of the gaff-topsail catfish, *Bagre marinus*, and the silver or sea catfish, *Galeichthys felis*, which were collected in the vicinity of Palmetto Key, Florida. Various morphological and embryological aspects of these two catfishes are discussed under the following headings:

External Anatomy.

2. A distinguishing character which seems to have been generally overlooked, is the posterior margin of the anal fin, which in *B. marinus* has a prominent V-shaped indentation and in *G. felis* a comparatively straight border. The cross-sectional shape of the maxillary barbels of the two species is not as clearly diagnostic as a distinguishing character as it has been described to be.

3. The pelvic fins of mature (or nearly mature) female *G. felis* have extraordinary, fleshy, hook-like protuberances on the adaxial surfaces; the males not infrequently exhibit a similar, though far less well developed, structure. Neither male nor female *B. marinus* possess corresponding modifications of the pelvics.

4. The pelvic fins of mature females of both forms are considerably larger, in proportion to the length of the fish, than in mature males of the same species. The sexually dimorphic character of the pelvic fins of *B. marinus* is apparent both as to size and shape.

Morphology of the Alimentary Tracts and the Feeding Habits.

5. The parietal peritoneum in *G. felis* appears almost grayish, due to minute black pigment spots which are abundant over its otherwise white surface, and which are more numerous on the dorsal surface of the coelom than on the lateral and ventral walls of the body cavity. The peritoneum of *B. marinus* lacks any melanistic pigmentation, and is a clean, silvery white.

6. The fundamental pattern of the gastro-intestinal tracts is the same in both species. Yet there are minor differences between the two which are constant for each form. Among these is the fact that the length of the intestine in *B. marinus* is longer in proportion to the size of the fish than in *G. felis*.

7. Stomach content analyses show that there is no significant difference in the diets of these two species. Both forms are completely omnivorous. There is certainly no evidence for gastric incubation in *G. felis* and *B. marinus*, although the eggs of these catfish are apparently not an entirely unacceptable item of diet at times.

Osteology.

8. The present studies show that the high degree of specialization in the skull structure so characteristic of the Nematognathi is well exemplified by these two species. Thus the bones of the skull are solidly fused together in both forms so as to form the typical cephalic shield. The fundamental patterns of the skull structure are essentially similar, yet there are many distinct differences, not only in the shape of the individual bones and the whole cephalic shields, but also in the fontanelles and foramina; these are described in some detail.

9. A nuchal shield lies just behind the posterior process of the supra-occipital, and in contact with its rear margin, in both species. These structures are much alike in the two forms, but show characteristic differences.

10. Studies of the lower jaw and opercular series show several interesting specializations. Among these is the complete disappearance of the subopercular (coincident with that of the parietals, opisthotic, and symplectic of the skull), and the relation of the metapterygoid and pterygoid bones.

11. The main elements of the pectoral girdles are the cleithra and coracoids, and the articulation of these girdles in both forms is accomplished by prominent cleithral prongs which fit into deep sockets on the base of the skull. The articulations of the serrated pectoral spines with the girdles are highly complex, involving defensive locking-mechanisms and sound-production.

12. The pelvic girdles in these catfish are much alike, although that of *B. marinus* is characterized by a pair of broad flat posterior processes on the basipterygia.

13. The caudal skeletons are characteristic of the less specialized homocercal tail, as indicated by the long urostyle and the number and disposition of the hypural bones.

Anatomy of the Inner Ear.

14. The inner ears of *G. felis* and *B. marinus* are almost identical in structure. Each has a large rounded utriculus, with its utricular otolith or lapillus, above, and a smaller elongate sacculus, with its saccular otolith or sagitta, below. Each also has a small sac-like outgrowth from the sacculus, the lagena, the forerunner of the spirally twisted cochlea of higher vertebrates; these lagenae each have a characteristic otolith, the asteriscus.

15. In almost all fishes the sagitta is the largest otolith and the lapillus tends to be small and insignificant, although in some forms the sagitta is small and the asteriscus is relatively large. In *G. felis* and *B. marinus*, however, the utricular otolith or lapillus is much enlarged and dwarfs the sagitta and asteriscus by comparison. The lapilli of these adult catfishes may be as much as 15-16 mm. in diameter.

Embryology.

16. The eggs of *B. marinus* and *G. felis* are much alike, although those of *B. marinus* are, on the average, slightly larger. Many of the characters which serve as a means of distinguishing these catfish as adults are useful in separating the later egg stages of the two forms—e.g., the barbels.

17. Studies of the gonads of these catfishes indicate that the main time of spawning for *G. felis* in 1938 on the west coast of Florida was June and July, while *B. marinus* spawned about a month earlier in this locality in that year.

18. Observations on the gonads of a limited number of apparently maturing females of both forms taken in February, March and April, indicate that the increase in size of the eggs at this season is extraordinarily rapid, and that there is relatively little change in egg size from immediately after the time of spawning in the spring and early summer to January and February. In other words, the tremendous increase in bulk of the maturing eggs in both forms is mainly confined to the four or five months immediately preceding spawning.

19. There is probably considerable variation in the size at which female *G. felis* first mature; this range is roughly from 12-20 cm., with the majority of individuals maturing for the first time near the upper end of the scale.

20. The total number of mature eggs produced by the females of these two catfish is usually from 20-40 per individual, although there are some instances where the numbers are smaller or larger than these limits.

21. The numbers of eggs carried in the mouths of the orally gestating males vary greatly in both forms, the average being 10-30. A single female can apparently produce more eggs than a single male can carry in his mouth, which, in the light of other evidence, indicates that polygamy is not uncommon among these forms.

22. The eggs in the mouth of any individual male are usually all in the same stage of development, although there are exceptions. The young remain in the parent male's mouth long after hatching, in many instances up to the time when the yolk sac is completely absorbed. The incubatory period on the west coast of Florida is probably about 6-8 weeks long. The young taken from the mouths of parent males were often found to have been feeding independently, as evidenced by the presence of small crustacea in their stomachs.

23. The earliest stage of development in this collection is represented by a number of specimens in which the eye and lens are clearly differentiated, mesodermal segmentation has progressed a long way, the somites being evident over the greater part of the entire length of the fish, neuromeres are distinctly visible, the pectoral limb buds are apparent, and the otoliths have formed. A possible explanation of the lack of earlier stages in the mouths of orally gestating individuals may be that the eggs are first deposited in a sandy depression and subsequently taken into the mouth of the parent male.

24. The later stages show the characteristic "coiling" of the body, the time at which the main steps in organogenesis occur, and various external and internal developmental features of interest. All available stages have been studied as whole mounts, and in sagittal and frontal sections.

25. Studies on the rate of development indicate that in 1938 on the west coast of Florida, hatching occurred in about a month, and that the larvae were retained in the parents' mouths from 2-4 weeks thereafter.

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EXPLANATION OF THE PLATES.

PLATE I.

A. Dorso-lateral view of the utriculus and semi-circular canals of *Bagre marinus*. The sacculus has been removed.

B. Side view of the inner ear of *Galeichthys felis*. Note the large size of the utriculus.

PLATE II.

Otoliths from *Galeichthys felis* and *Bagre marinus*.

A. Views of the two sides of the lapillus from *B. marinus*.

B. The same from *G. felis*.

C and **D.** Dorsal and ventral aspects of the asteriscus of *B. marinus*.

1-6. Various developmental stages of the eggs and larvae of *Galeichthys felis*.

PLATE III.

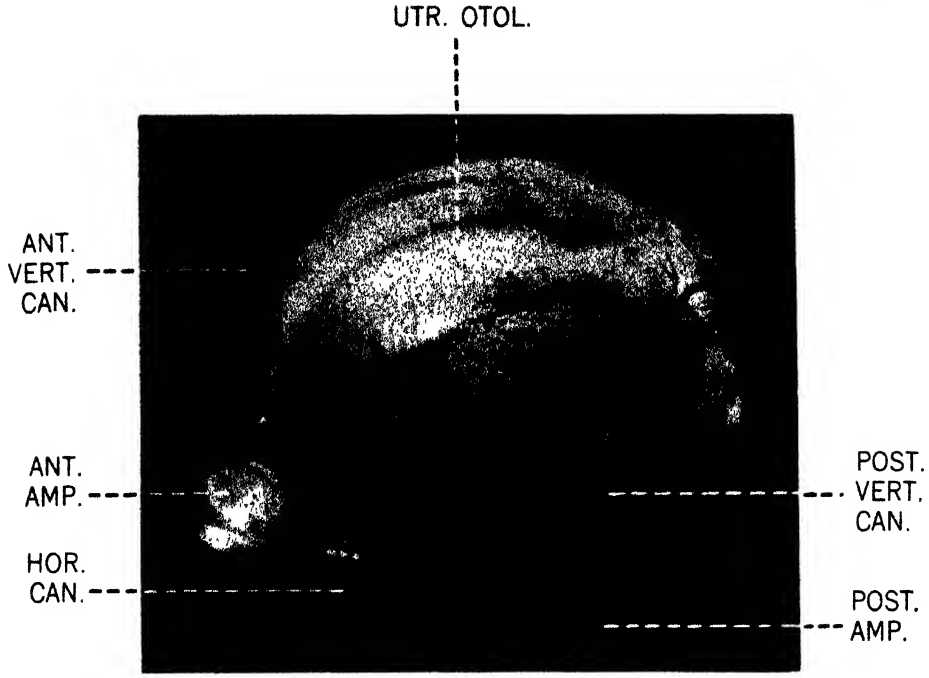
1-3. Whole mounts of the embryos of *Galeichthys felis* in different stages of development.

PLATE IV.

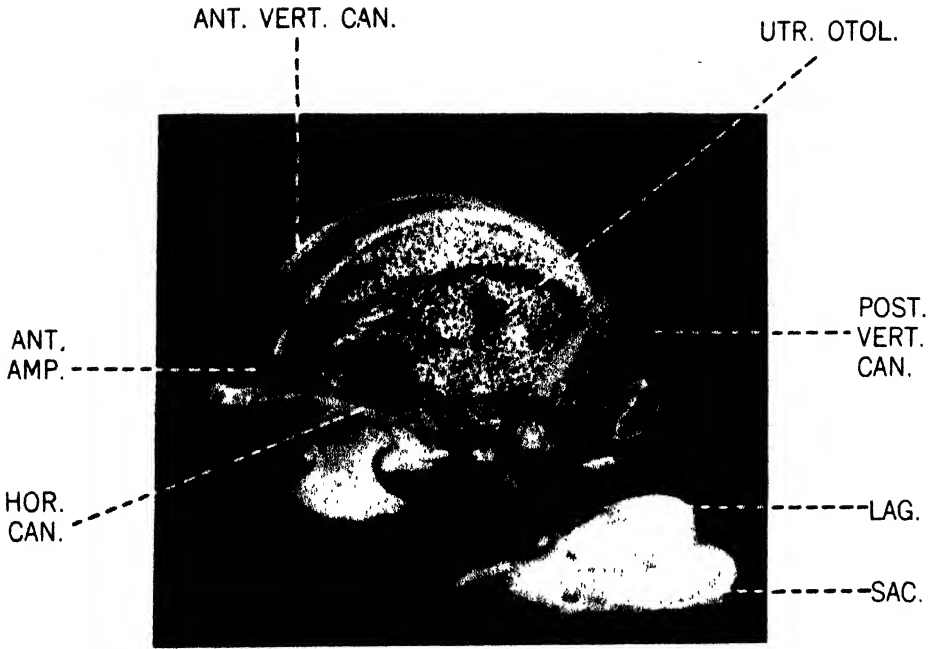
1-5. Sagittal and frontal sections of *Galeichthys felis* embryos in various stages of development. See text for description.

PLATE V.

1 and **2.** Sagittal sections through the anterior part of the body of *Galeichthys felis* in the "coiling" stage of development.

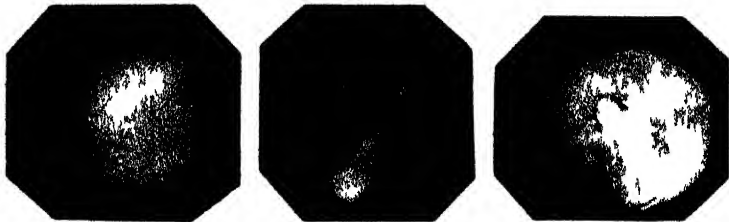


A.



B.

MORPHOLOGICAL AND EMBRYOLOGICAL STUDIES ON TWO SPECIES
OF MARINE CATFISH, BAGRE MARINUS AND GALEICHTHYS FELIS.



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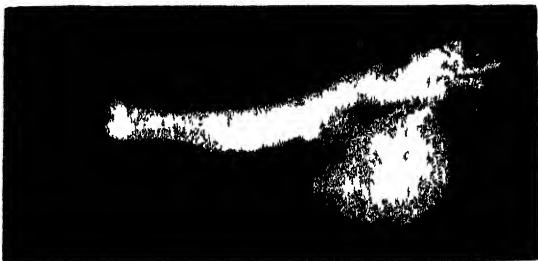
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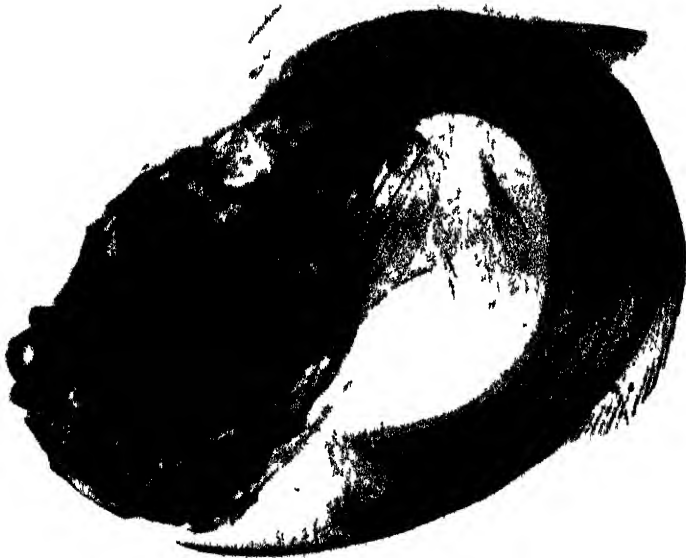
MORPHOLOGICAL AND EMBRYOLOGICAL STUDIES ON TWO SPECIES
OF MARINE CATFISH BAGRE MARINUS AND GALEICHTHYS FELIS



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MORPHOLOGICAL AND EMBRYOLOGICAL STUDIES ON TWO SPECIES
OF MARINE CATFISH, BAGRE MARINUS AND GALEICHTHYS FELIS



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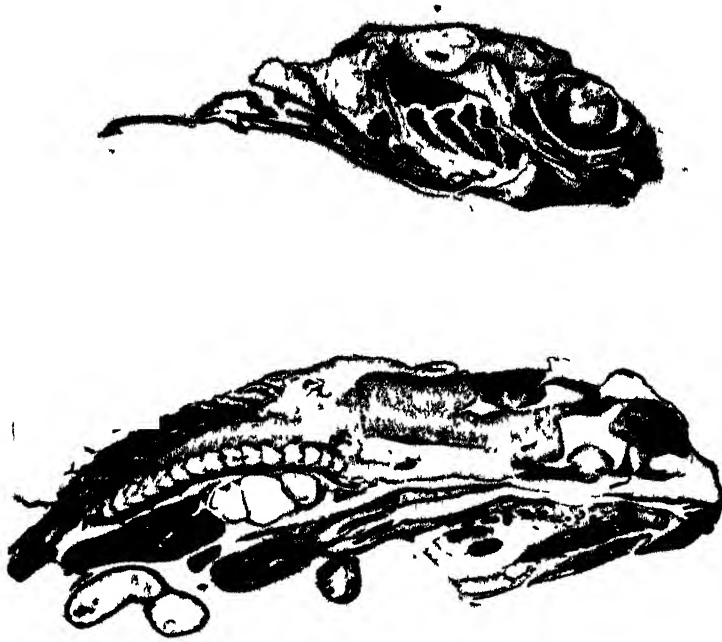


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MORPHOLOGICAL AND EMBRYOLOGICAL STUDIES ON TWO SPECIES
OF MARINE CATFISH, BAGRE MARINUS AND GALEICHTHYS FELIS.



2

MORPHOLOGICAL AND EMBRYOLOGICAL STUDIES ON TWO SPECIES
OF MARINE CATFISH BAGRE MARINUS AND GALEICHTHYS FELIS

14.

Propagation of the Electric Impulse along the Organs of the Electric Eel, *Electrophorus electricus* (Linnaeus).

C. W. COATES,
New York Aquarium,

R. T. COX, W. A. ROSENBLITH,
Department of Physics, New York University

&

M. VERTNER BROWN,
Department of Physics, College of the City of New York.

(Plate I; Text-figures 1-3).

Observations already reported¹ have shown that in the discharge of the electric organs of the electric eel a pulse of potential gradient runs along the organ from anterior to posterior. The speed of the pulse was roughly estimated by several methods and was found much higher than the highest recorded speeds of impulses along nerves. The cathode-ray oscillograph used in these observations did not, however, make possible anything better than rough determinations of the speed. A more suitable cathode-ray oscillograph² having lately become available, it seemed worth while to attempt more accurate measurements.

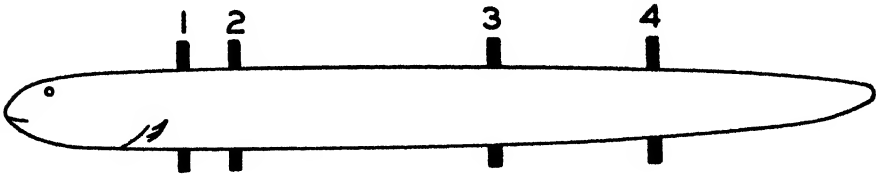
The method employed is almost the same as one of those used before. The fish is taken out of water and laid in an insulating trough. The trough is grooved across one side every 10 cm. and aluminum strips inserted in any of these grooves make good electrical connection through the skin to the large electric organs and serve as electrodes for connecting the organ to the oscillograph. Text-fig. 1 shows the positions of these electrodes on the fish in one of the observations. Electrode 1 was at the anterior end of the large organ and electrode 2 was 10 cm. behind it. With these positions a conveniently measurable voltage was developed in the segment of the organ included between the two electrodes. The first two electrodes were consequently kept in these positions during all the observations. Electrode 3 was placed at a distance behind electrode 2 differently chosen in the various observations. Electrode 4 was placed far enough behind electrode 3 that the peak voltage between 3 and 4 was comparable to that between 1 and 2.

Oscillographic traces were photographed with three different connections of the electrodes to the oscillograph. First electrodes 1 and 2 were connected to the vertically deflecting plates of the oscillograph tube. When the discharge of the eel develops a voltage between these two electrodes,

¹ Coates, C. W., Cox, R. T., and Granath, L. P. The Electric Discharge of the Electric Eel, *Electrophorus electricus* (Linnaeus). *Zoologica*, New York, 1937. Vol. 22, Part 1, pp. 1-32.

² Allen B. Dumont. Type 175A Oscillograph.

this voltage applied to the plates deflects the beam of electrons in the oscillograph tube. The luminous spot which the beam makes where it strikes the fluorescent screen at the end of the tube rises and falls with the voltage developed in this segment of the organ, the displacement of the luminous spot at any instant being proportional to the voltage existing at the same instant between the electrodes. While the discharge of the fish is causing this vertical motion, voltage from a "sweep circuit," applied to the horizontally deflecting plates of the oscillograph tube, carries the luminous spot horizontally across the fluorescent screen at a constant rate. The luminous spot thus traces a graph, which can be photographed, in which the voltage between the electrodes is plotted vertically against the time plotted horizontally.



Text-figure 1.

Position of electrodes for determining voltage at anterior and posterior ends of electric organs.

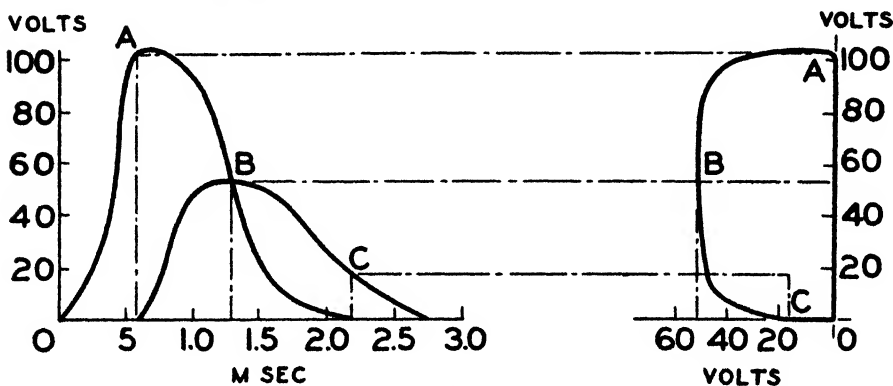
Next the vertically deflecting plates were connected to electrodes 3 and 4 on the fish and the graph of voltage against time was obtained for the discharge in this posterior segment. Plate I, Figs. 1 and 2, show traces obtained for the discharge of the two segments in an eel 108 cm. long. The sweep circuit could not be synchronized with the discharge of the organs. Consequently traces of a number of discharges occurring during successive horizontal sweeps of the electron beam are shown overlapping in each figure.

These two figures show the voltage-time relation for each segment, but they give no indication of the time-lag between the pulses in the two segments. To determine the time-lag the fish was connected to the oscillograph in a third way. The sweep circuit was disconnected from the oscillograph tube, the anterior segment 1-2 was connected to cause a vertical deflection of the electron beam, and the posterior segment 3-4 was connected to cause a horizontal deflection. The trace obtained with this connection is shown in Plate I, Fig. 3. Because the voltage rises in the anterior segment before it begins to rise in the posterior segment, the initial deflection is vertical. This shows as the vertical side at the right of the loop. The right-angled bend of the trace at its upper left corner indicates that the voltage in the anterior segment has ceased to rise but has not started to fall at the instant at which the voltage begins to rise in the posterior segment. After this, the voltage starts to fall in the anterior segment while remaining near its peak in the posterior segment. Finally it falls in both together and the loop is closed.

If the time-lag between the discharges in the two segments were known, it would be possible to construct the trace shown in Fig. 3 from measurements on the two traces shown in Figs. 1 and 2. For if the time-lag were known, corresponding instants on the time-axes of the two traces could be paired, and voltages simultaneously existing in the two segments could be determined. A graph showing the voltage in the anterior segment plotted vertically against the simultaneous voltage in the posterior segment plotted horizontally would be similar to the loop of Fig. 3, which was obtained with the oscillograph when the two segments were connected respectively to the vertically and horizontally deflecting plates. Conversely, by assuming various

values for the time-lag and plotting the corresponding values of the two voltages one against the other, there will be obtained a number of graphs of which the one most like the recorded loop will have its assumed time-lag nearest the actual time-lag.

This procedure is illustrated by Text-fig. 2. The oscillographic traces copied in this figure were obtained with an eel 124 cm. long. The traces of the discharge in the anterior and posterior segments are superimposed with an assumed time-lag of 0.6 millisecon. so as to give a loop analogous to the one which was recorded. Points A, B, and C, corresponding to three instants during the discharge, serve to illustrate the construction. A shows the voltage in the anterior segment (plotted vertically) at the start of the discharge in the posterior segment. B shows the voltage in the anterior segment at the instant at which it is equal to that in the posterior segment (plotted horizontally). C shows the voltage in the posterior segment at the end of the discharge in the anterior segment.



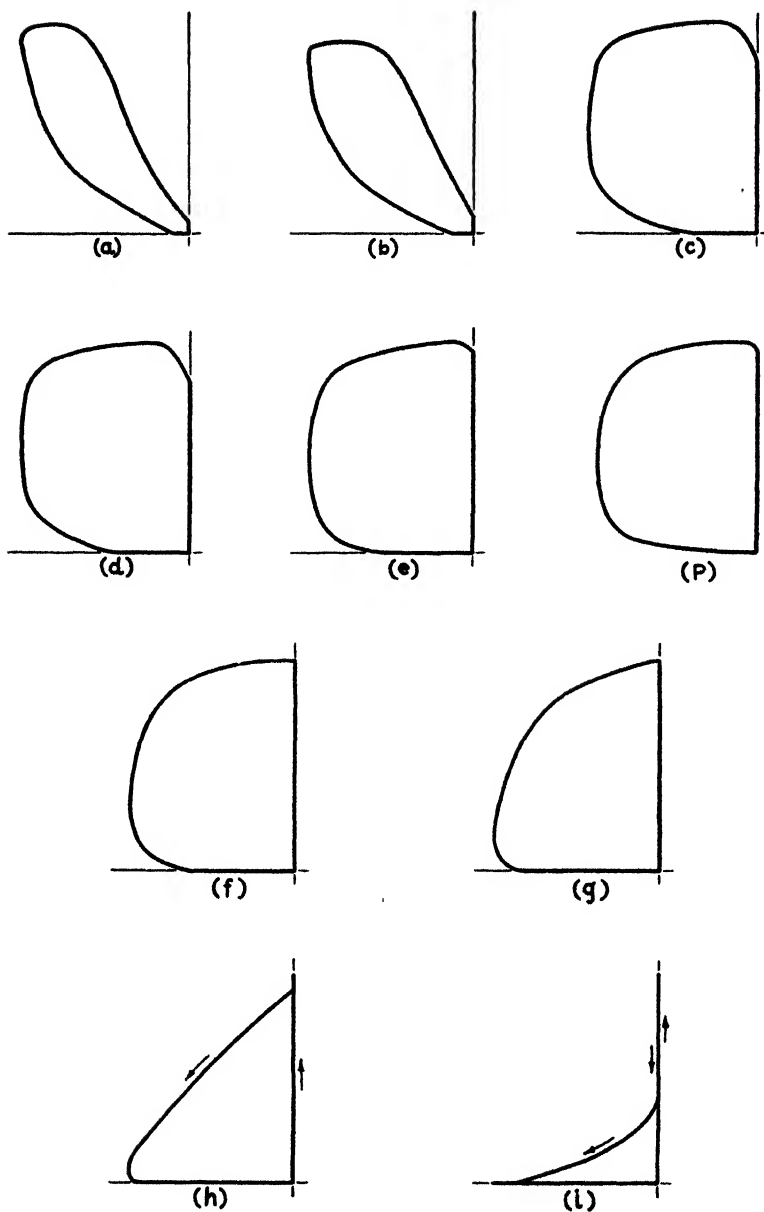
Text-figure 2.

Construction of graph of anterior voltage vs. posterior voltage by superposition of graphs of anterior voltage vs. time and posterior voltage vs. time. Assumed time-lag, 0.6 millisecon. (The scale of voltage is only roughly approximate).

Text-fig. 3 shows a more extended example of the same construction. The traces copied here were obtained with an eel 167 cm. long. The graphs (a)–(i) have been constructed as in Text-fig. 2 with various assumed time-lags between the starts of the discharge in the anterior and posterior segments. Graph (e) in the second row is seen to be very similar to the loop drawn next to it, which is a copy of the photographically recorded loop.

The time-lag between the starts of the rising voltage in the two segments is thus found to be 0.6 millisecon. Now the instant at which the voltage between the electrodes 1 and 2 starts to rise is the instant at which the front of the pulse of potential gradient starts down the organ from electrode 1 at the anterior end. Similarly the instant at which the voltage starts to rise between electrodes 3 and 4 is the instant at which the front of the pulse reaches electrode 3, for as soon as the front of the pulse passes a given point that point will be at a different potential from points farther along the organ. Hence the time-lag found, 0.6 millisecon., is the time required for the front of the pulse to traverse the distance from electrode 1 to electrode 3. This distance was 60 cm. Dividing the distance by the time-lag, we find the average speed of the pulse along the anterior 60 cm. of the large organ to be 100 cm. per millisecon. or 1,000 meters per sec.

With the same fish oscillographic traces were photographed with elec-



Text-figure 3.

Construction of graph of anterior voltage vs. posterior voltage with various assumed time-lags.

Graph	a	b	c	d	e	f	g	h	i
Assumed time-lag, (milliseconds.)	.06	0.1	0.3	0.5	0.6	0.7	0.9	1.2	1.8
Computed speed of pulse, (meters per second.)	10,000	6,000	2,000	1,200	1,000	860	670	500	330

The photographically-recorded trace (P) is shown for comparison at (e).

trodes 1 and 2 in the same positions as in Text-fig. 1 but with electrodes 3 and 4 at 40 cm. and 60 cm. respectively from the anterior end. The time-lag between the starts of the rising voltage in the anterior and posterior segments was again determined by the procedure just described and was found to be only 0.15 millise., approximately. From this result the average speed of the pulse along the anterior 40 cm. of the organ is found to be about 2,500 meters per sec.

The pulse takes 0.6 millise. to travel along the organ 60 cm. from the anterior end and 0.15 millise. to travel 40 cm. from the anterior end. The difference of these two time-lags, 0.45 millise., is the time required for the pulse to traverse the segment of the organ between 40 cm. and 60 cm. from the anterior end. The average speed of the pulse along this 20 cm. stretch is thus only 450 meters per sec.

None of these determinations can be taken as at all precise. Nevertheless it is clear that the speed of propagation of the pulse along the organ diminishes from anterior to posterior. The speed at the anterior end of the organ must then be greater than the average speed along the anterior 40 cm., which was reckoned as 2,500 meters per sec. Even with allowance made for the inaccuracy of this measurement, it seems safe to take 2,500 meters per sec. as a minimum estimate for the speed at the anterior end. The large electric organ of this fish was at least 120 cm. long, and the average speed of the pulse over the segment between 40 cm. and 60 cm. from the anterior end was found to be 450 meters per sec. Considering the fall in speed toward the posterior end it seems safe, after allowing for the inaccuracy of the measurement, to take 450 meters per sec. as a maximum estimate of the speed at the posterior end. The ratio of the speed at the anterior end to that at the posterior end must then be greater than 5 to 1.

Measurements were made in all on three fish of different lengths. The results are summarized in the following table.

TABLE 1.

Propagation of pulse along large organs of three eels of different sizes.

Eel	Length (cm.)	Circumference at anterior end of large organ (cm.)	Distance from anterior end to electrode 3* (cm.)	Time-lag (millise.)	Speed (meters per sec.)
I	108	20.5	40	Between 0.25 and 0.3	About 1500
II	167	34	40	0.15	2500+
			60	0.6	1000
III	124	25	20	0.1—	2000+
			40	0.45	900

* Electrode 1 was always at the anterior end of the large organ. Hence this distance is the distance traversed by the pulse during the measured time-lag. The speed is computed from the distance and the time-lag.

In the electric eel the electric organs lie parallel to the spinal cord. From special large cells, the electric nerve cells, lying in the cord, nerves branch out to the adjacent parts of the organs. The discharge in every part of the organ is excited by the nerves running to that part. For if the cord is cut at any point, parts of the organ posterior to the cut do not discharge. On the other hand, if the organ is transected at any point without injury to the cord, the segment of the organ posterior to the transection still discharges.

The path traversed by the nervous impulse which initiates the discharge at any point is certainly no shorter than the distance to that point along the body of the eel. It seems necessary then to conclude either that the nervous impulse travels along the cord as fast as we have found the electric pulse traveling along the organ or else that there is some special mechanism which delays the discharge in the anterior part of the organ while the nervous impulse runs down the cord to initiate the discharge in posterior parts.

If we take the first of these hypotheses and assume a speed of the nervous impulse along the fibers in the cord as high as 2,500 meters per sec., and if we apply the rule given by Blair and Erlanger³ that the speed is proportional to the square of the diameter of the fiber, then we find that the fiber must have a diameter of about 140 microns or .014 cm. We have not found a record of the size of the nerve fibers in the spinal cord of the electric eel, but a diameter of 140 microns is several times greater than that of the largest ordinary nerve fibers. If, instead of following the rule of Erlanger and Gasser, we adopt the conclusion of other investigators that the speed is proportional to a power of the diameter between the first and second, then still larger nerve fibers must be assumed for the electric eel.

The evidence which we have on the second hypothesis, that of a special process delaying the discharge in the anterior part of the organ, is as yet slight and inconclusive.

It is at any rate easy to see how the effective use of the organ requires the pulse to travel along it at a much higher speed than that at which nervous impulses are commonly transmitted. The point is most readily discussed in terms of the description of the organ as a series of galvanic elements effectively insulated from each other except when, during the discharge, a transient drop in the electrical resistance between adjacent elements joins them briefly in series⁴. This series connection persists only for about 1.5 millisecc. at any point in the organ. The front of the pulse at any instant is the point on the organ at which the connection is just beginning to be made. If the front travelled down the organ at a speed of 100 meters per second, or 10 cm. per millisecc. (which is near the highest speed recorded even in mammalian nerve) the length of the segment connected at any one time would be only 15 cm. As soon as the front had travelled that far along the organ, the connection would be broken behind it as fast as it was made in front. The highest voltage developed would thus be only a fraction of what is developed with the actual speed. The discharge would, it is true, be prolonged by the slower propagation, but this advantage could hardly offset the disadvantage of the lower voltage in repelling the enemies of the fish and stunning its prey, especially since the fish can now repeat its discharge with such rapidity as to have much the same effect as prolonging it, perhaps with a greater effect physiologically.

It thus appears that the evolution of the electric eel has developed a mechanism for the propagation of the pulse along the organ which circumvents whatever factor limits in other animals the speed of the impulse along nerve fibers, and that without this mechanism—whatever it is—the electric power of the eel would be much less effective. It also appears, however, that this mechanism is itself subject to some limitation, for it does not make the discharge exactly simultaneous at every point of the organ. Because of the time lag, the peak voltage between the extremities of the organ is less than the sum of the peak voltages developed in all its segments. Measurements on an electric eel about 170 cm. long showed that the voltage developed in the anterior four-fifths of the large organ is practically as great as that developed between its extremities. This indicates that the posterior fifth of

³ Blair, E. A., and Erlanger, J., *Am. J. Physiol.*, 106, 524 (1933).

⁴ Cox, R. T., and Coates, C. W. Electrical Characteristics of the Electric Tissue of the Electric Eel, *Electrophorus electricus* (Linnaeus). *Zoologica*, New York, 1938. Vol. 23, Part 2, pp. 203-212.

the organ is not fully joined in series until the connection at the anterior end has begun to be broken. Consequently in this eel the posterior fifth of the organ has little effect other than to prolong the discharge.

Our observations afford only a narrow basis for the comparison of the speeds of the pulse in eels of different lengths. However it seems that there is probably an upper limit to the speed attainable and that there is consequently an increase, as the eel grows, in the time lag between the discharges at the extremities of the organ. It seems therefore a quite reasonable inference that, because of this factor, growth of the eel beyond a certain length would increase the need of prey faster than the additional effectiveness of the discharge would help in its capture. What this length would be we can not say from our observations. The longest electric eel that the New York Aquarium has had was about 2.7 meters long, and this is about the greatest length recorded. It would seem unlikely that growth beyond this point would be helpful to the eel.

EXPLANATION OF THE PLATE.**PLATE I.**

Oscillographic traces of the discharge of an electric eel 108 cm. long.

- Fig. 1. Voltage-time graph of anterior segment. Electrodes at anterior end of Large Organ and 10 cm. behind. Length of horizontal base corresponds to 4 milliseconds. The peak is about 100 volts.
- Fig. 2. Voltage-time graph of posterior segment. Electrodes 40 cm. and 70 cm. from anterior end of Large Organ. Scale same as in Fig. 1. (The discharge of lower voltage is of the intermediate type).
- Fig. 3. Graph of voltage in anterior segment (vertically) against voltage in posterior segment (horizontally). (The short horizontal trace is made by the discharge of the Bundles of Sachs.)



FIG. 1.

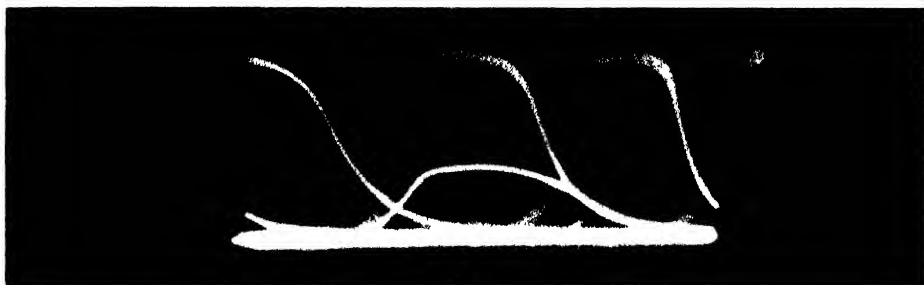


FIG. 2.

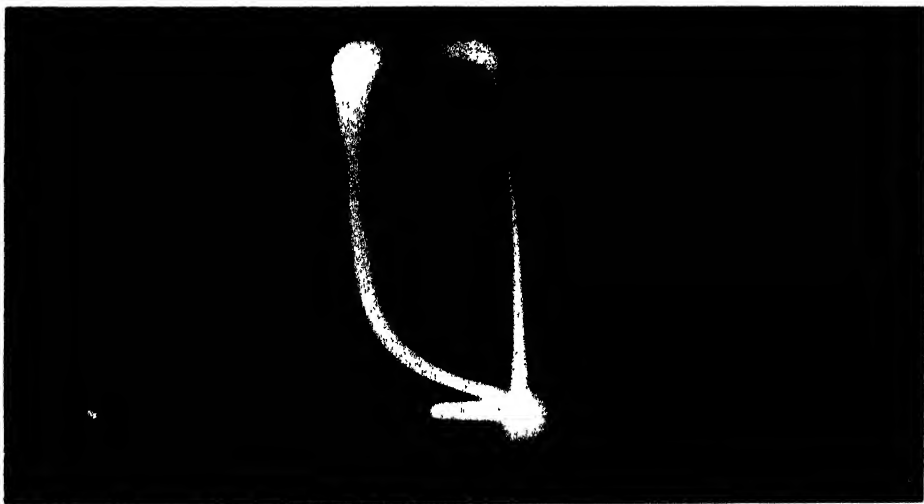


FIG. 3.

PROPAGATION OF THE ELECTRIC IMPULSE ALONG THE ORGANS OF THE
ELECTRIC EEL, *ELECTROPHORUS ELECTRICUS* (LINNAEUS).

15.

Notes on the Display Forms of Wahne's Six-plumed
Bird of Paradise.

LEE S. CRANDALL

Curator of Birds, New York Zoological Park

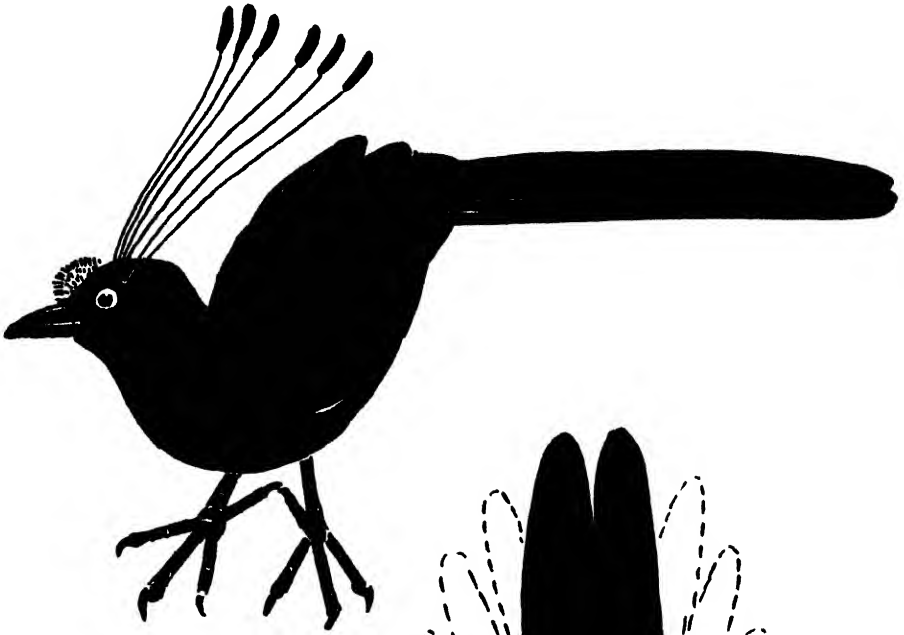
(Text-figures 1-3).

The display forms of the short-tailed members of the genus *Parotia*, as typified by those of the Greater Six-plumed Bird of Paradise (*P. seflata*) and Lawes' Six-plumed (*P. l. lawesi*), are now well known. But those of Wahne's Six-plumed (*P. wahnesi*) have caused much conjecture, because of the remarkably long tail. It was to be supposed that some variation from the usual forms would be found.

Wahne's Six-plumed Bird of Paradise was unknown in captivity until 1931, when a single male, brought from northeastern New Guinea by Mr. F. Shaw-Mayer, was secured by the Zoological Society of London. No further importations were made until 1939, when Mr. Mayer arrived in London with another shipment. Through the kindness of M. Jean Delacour, we obtained an adult male from this lot. The bird arrived in New York on August 17, 1939, and about October 20 began to molt. By the end of February, 1940, the change had been completed, the four months' molting period being the average for adult males of this genus.

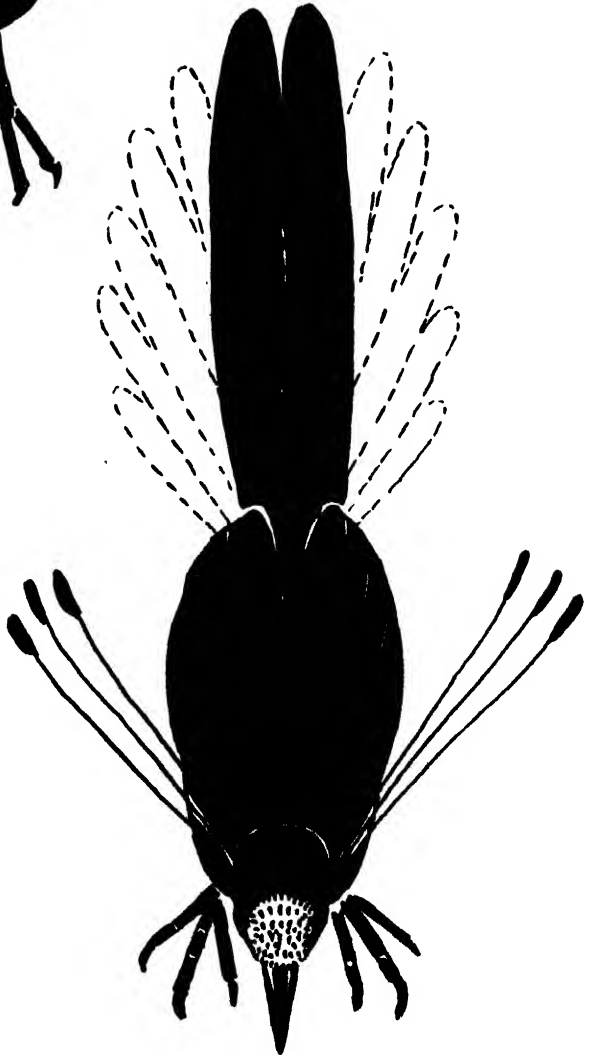
Once the molt was complete, the bird became very active, in marked contrast to the usually phlegmatic conduct of male Six-plumes of other species. Displays were soon observed, and are recorded in the following notes.

When about to display on the ground, the bird stands with its body in a horizontal position, with the wings held closed but high, in order to clear the slightly loosened flank feathers. The tail is turned sideways, usually to the left (Text-fig. 1). The bird feigns picking at the ground, then suddenly throws the body forward and downward with the head turned under the breast, so that its crown is nearly parallel with the ground (Text-fig. 2). The tail now becomes the center of attention, for it is thrown straight upward, behind the crouching body. While all else remains immobile, the graduated lateral feathers are now rapidly opened and closed, the central pair remaining fixed. After this fan-like effect has been obtained perhaps five or six times, the bird suddenly drops the tail and throws its body into an upright position. Simultaneously, the long feathers of the back and flanks are raised to form the "umbrella" well known in other forms of *Parotia*, and the head plumes are thrown far forward, three on each side of the crown (Text-fig. 3). The brilliant breast plate is noticeably flat and lies between a slight extension of the feathers of the upper neck and the erected flank and breast plumes. With the head now extended to its greatest possible height, the bird turns it rapidly from side to side, causing the tabs on the plumes to rotate in the typical manner. Several mincing, short steps are now taken along the



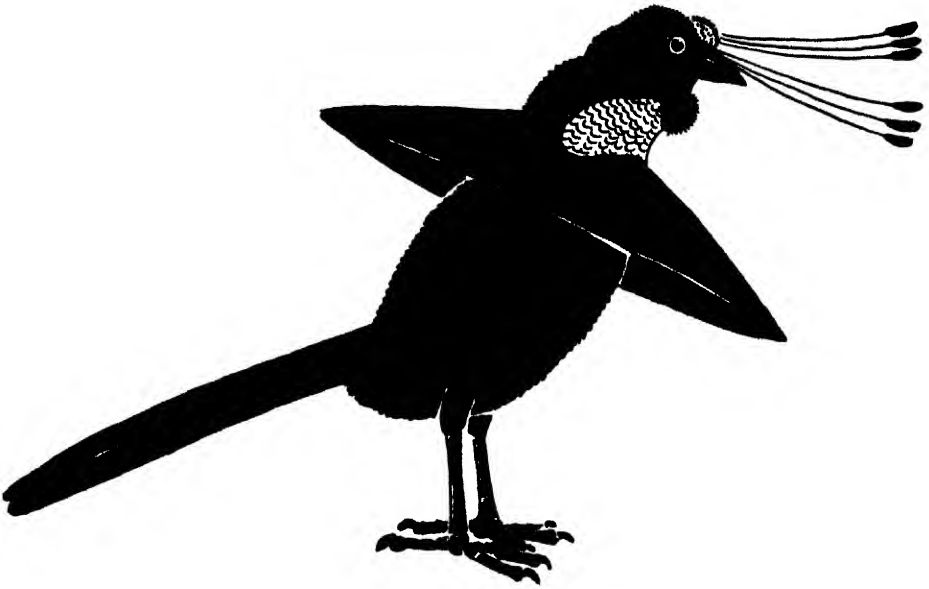
Text-figure 1.

Parotia wahnesi. Position taken preliminary to display.



Text-figure 2.

Parotia wahnesi. First position of display, in which the tail is "fanned."



Text-figure 3.

Parotia wahnesi. Final position of the display, climaxed by "wobbling" of the neck.

ground, usually to the right. After moving perhaps a foot in this manner, the bird suddenly becomes immobile except for the neck, which is rapidly moved from side to side, between the head and breast plate. The display usually ends with this maneuver. During the upright form of the display, the tail takes a negligible part and may turn to either side or even drag on the ground.

In preparing to display off the ground, the bird moves about the perches, its body stiffly horizontal and the tail held to the side. When the chosen spot is reached, it throws itself directly into the upright form, the tail-fanning being omitted. The following display is then identical with that performed on the ground, including movement along the perch and "wobbling" of the neck.

While in the series of papers published by the New York Zoological Society on the display forms of Birds of Paradise, no attempt at correlation has yet been made, one point in relation to Wahne's Six-plumed is so striking that it should not be overlooked. The long tail of this species is very suggestive of that of *Astrapia rothschildi*. When it is recalled that the latter bird also "fans" the tail in display¹, and that the distribution of the two species is generally identical and restricted to a small area in northeastern New Guinea (mountains of the Huon Peninsula), the desirability of further investigation in the field is suggested.

¹ *Zoologica*, Vol. XI, No. 7, p. 81, 1932.

16.

Acute Hemorrhagic Gastro-enteritis in a Giant Panda.

LEONARD J. GOSS

Veterinarian, New York Zoological Park

The male giant panda, *Ailuropoda melanoleuca* (Daudin), in the collection of the New York Zoological Park, was found dead in its cage on the morning of May 6. In view of the comparative rarity of the animal in captivity and the paucity of records as to its pathology, we present here an account of its diet and the findings on autopsy.

The specimen was reported to be 14 months old when it was received on May 1, 1939, from China through the agency of Mr. Dean Sage, Jr. Its weight on arrival was 72 pounds. Its age when captured could not be learned, but it had been in captivity in China for some months, apparently confined by a chain or rope around its neck, for the hair was worn off in this area in a wide band, and the coat was generally in a dry, unhealthy condition. The type and amount of food supplied the animal in China and en route to New York could not be learned.

For eleven months previous to the arrival of the male, the female giant panda in our collection (8 months old on arrival) had been fed the following ration devised by Dr. C. R. Schroeder: Pablum, dried milk, raw eggs, raw green vegetables (carrots, lettuce, celery), oranges, codliver oil, brewers' yeast, bone meal and salt. The male specimen was put on this diet and readily consumed it.

During the twelve months the male was in the Zoological Park it made an average monthly weight increase of 8.1 pounds. However, 23 pounds were gained during the first 16 days and only 20 pounds were gained the last 4 months. This is in contrast to an average monthly gain of 9.5 pounds by our other panda, the female, for the 24 months she has been in captivity. Her average gain for the past 6 months is exactly the same as her two-year average, 9.5 pounds per month.

From time to time during the year that the male was in our collection, bamboo, sugar cane and cornstalks were introduced into the diet and both the male and the female consumed this starchy material with evident enjoyment. Eventually the source of supply became less dependable and the stalks were discontinued.

It soon became apparent that the male giant panda was not making satisfactory progress and the diet was suspected of being faulty. At intervals of about two months it ceased to feed for several days at a time and these periods were accompanied by frequent belching-like actions. Accompanying these attacks, quantities of yellow, tenacious, rubbery mucus streaked with blood were passed from the rectum. After each of these attacks the animal's appetite was impaired to such an extent that it would eat only a portion of some of the usual items in its diet—food that it had taken willingly before. As these digestive disturbances progressed, anal flatus was a marked symptom.

The stool was always very loose, being about the consistency and appearance of corn meal mush, and a formed stool was never passed. While this was to be expected, considering the elements of the diet, it was not felt that this was a satisfactory condition. In view of the well-developed denture of the panda, the large stomach, the consistency of the stool and the attacks of intestinal disturbances, it was decided that the animal should again be given roughage in the form of bamboo.

A small stalk of bamboo $\frac{1}{2}$ " in diameter and 8" long was offered. This aroused such interest in an otherwise lethargic animal and the results were so gratifying that the practice was continued. A small stalk of bamboo was given each day. Invariably the bamboo was stripped of its outside covering by the use of a paw and the teeth and the remaining stalk crushed and chewed in the powerful teeth and jaws. Small portions of the bamboo were fed daily and the results anxiously awaited. The appetite seemed improved, at least for the bamboo; the stool became formed, and the anal flatus desisted. Feeling that no untoward dangers were developing and that the animal was now conditioned to the bamboo, we increased the amount. At no time were more than three sticks 8" long fed the animal. Two and a half weeks following the introduction of bamboo into the diet, the panda developed a fatal enteritis. The morning before it died, it was found prostrated and breathing hard, the coat damp over the entire body. Close examination revealed the skin to be dry; it was assumed that the moisture on the coat was a result of lying in the animal's own fecal material. There was a spot of vomitus in the cage, consisting of the previous evening's meal, and a normal stool. The eyes were closed, the conjunctiva congested, in marked contrast to a very pale oral mucosa. A very watery, reddish-brown (blood) stool was passed, accompanied by griping. A diagnosis of acute enteritis was made. At 1 P.M. the animal appeared much brighter and was not adverse to moving about. At 7 P.M. it was up and around, steady on its feet and begging for food. Food was withheld and 1 pint of water was given per orum. It was felt that the crisis had passed and recovery was probable, but the animal was found dead at 7:30 A.M. the following morning.

Autopsy findings were: Body weight 170 pounds, about two quarts of clear watery transudate in the abdominal cavity. The mesenteric vessels were tremendously engorged. The serosa of the intestines was purple red in color, the mesenteric lymph glands swollen, hemorrhagic at the periphery and juicy. The intestines contained several quarts of blood-colored material containing small flakes of curd-like mucus. The gastric and intestinal mucosa were acutely hemorrhagic in color. The intestinal wall was thickened. The gastric and duodenal mucosa showed numerous small pits representing partially healed chronic ulcers. The spleen was pulpy and swollen. All other organs appeared normal. Bacterial cultures of the liver, spleen, and heart's blood were negative. Cultures of the intestinal content in tetrathionate broth and on brilliant green agar plates did not reveal any paratyphoid organisms. Death was attributed to an acute hemorrhagic gastro-enteritis. From the cultures made, bacterial infection is precluded. The part the bamboo in the diet played in producing death is problematical. It is thought that the alimentary tract was particularly susceptible to the abrasive action of bamboo in view of the fact that the animal had been on a soft diet up to $2\frac{1}{2}$ weeks before death. The ulcers found in the gastric and duodenal mucosa undoubtedly were contributing causes.

17.

Two New Species of Trematodes from the Deep Sea Scorpion Fish, *Scorpaena madurensis* Cuv. & Val.

ROSS F. NIGRELLI

New York Aquarium

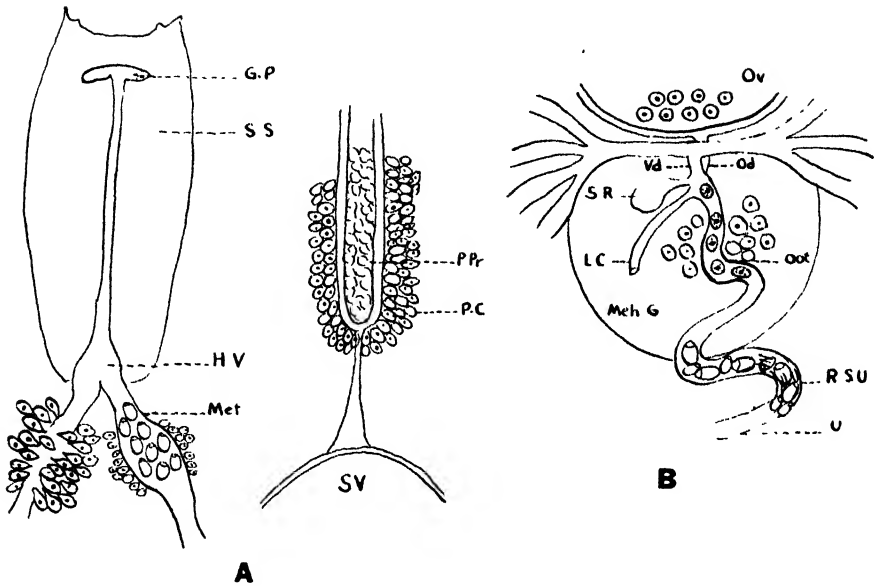
(Plate I; Text-figures 1 & 2).

Scorpaena madurensis (= *Sebastes madurensis*) inhabits the deeper waters off the Madeira Islands. Specimens were sent to the New York Aquarium in an exchange with the London Aquarium. Two species of trematode parasites belonging to the families Hemiuridae and Allocreadiidae were found in the stomach and intestine respectively. Morphological studies on these worms indicated that they were new and the names *Tubulovesicula madurensis* and *Podocotyle atzi* were given them by Nigrelli (1939).

Tubulovesicula madurensis.

(Plate I, Fig. 2; Text-figure 1).

The following description is based on four specimens. The worms are cylindrical, spindle shaped, and in all cases the tail portion was completely everted. Total length 7.35 mm.; tail appendage proper 2.69 mm. Width of worms, taken in the middle third of the body, 1.63 mm. Pre-oral lip and cervical glands present, the former measuring .0435 mm. in length. Oral sucker .251 × .287 mm., subterminal; pharynx contiguous to oral sucker, measuring .161 × .194 mm.; esophagus short, .111 mm. The proximal part of the ceca is lined with cuticula for a short distance, ceca terminating at the posterior tip of the tail appendage. Acetabulum larger than oral sucker, slightly forward in the anterior third of the body, measuring .643 × .659 mm. Testes ovoid in shape, ventral, post-acetabular, more or less obliquely placed, separated from one another by uterine coils. Right testis measures .444 × .498 mm.; left testis .413 × .532 mm. The seminal vesicle is short and broad, tubular, antero-dorsal to the testes, post-acetabular, measuring .465 × .165 mm. *Pars prostatica* long, surrounded by numerous prostate cells, post-acetabular, measuring 1.28 mm. in length. *Ductus hermaphroditicus* enclosed in a sinus sac and opening into the genital atrium. Sinus sac large, shield-shaped, measuring .150 × .270 mm. Opening of the atrium at the level of the pharynx. Ovary oval shaped, immediately behind the testes, measuring .348 × .442 mm. Seminal receptacle measures .042 × .032 mm. Laurer's canal present. Shell gland immediately posterior to the ovary, .233 mm. in diameter. Vitelline glands tubular, extending to the extra-cecal area, seven lobes in number, three left, four right, measuring 1.50 × .046 mm. *Receptaculum seminis uterinum* present. The uterus descends to the posterior end of the body but does not enter into the tail appendage, or only slightly so. It then winds anteriorly, mostly intercecal, to one side of the



Text-figure 1.

Reproductive organs of *Tubulovesicula madurensis*. **A.** Part of the terminal reproductive system. G.P., genital pore; S.S., sinus sac; H.V., hermaphroditic vesicle; Met., metraterm; P.Pr., pars prostatica; P.C., prostate cells; S.V., seminal vesicle. **B.** Ovarian complex. Ov., ovary; Od., oviduct; Vd., vitelline duct; S.R., Seminal receptacle; L.C., Laurer's canal; Oot., ootype; Meh. G., Mehlis' gland; R.S.U., *Receptaculum seminis uterum*; U., uterus.

ovary, and in between the testes. The metraterm portion of the uterus measures .38 mm. in length. Eggs thick shelled, operculated and embryonated, measuring .012-.015 \times .018-.025 mm. The excretory stem bifurcates just immediately behind the level of the testes; the arms of the branches re-uniting at the level of the pharynx, on the dorsal side.

The genus *Tubulovesicula* was created by Yamaguti (1934) to include the following hemiurids: *T. spari* Yamaguti (1934) from *Sparus macrocephalus*; *T. anguillae* Yamaguti (1934) from *Anguilla japonica*; and *T. muraenesocis* Yamaguti (1934) from *Muraenesox cinereus*. The first of these species was designated as type. This investigator included in this genus *T. angusticauda* (Nicoll, 1915) (= *Ectenurus angusticauda* Nicoll, 1915) also from *Muraenesox cinereus*. According to Yamaguti, however, this species differs from the form that he described from the same host in the size of the eggs, and in the posterior extent of the seminal vesicula and the pars prostatica. Yamaguti further indicated in his paper that the form described by Layman (1930) as *Lecithaster lindbergi* also should be referred to the genus *Tubulovesicula*. Since then two other species have been included in the genus. Park (1936) described *T. californica* from the stomach of *Enophrus bison*, a sculpin fish from the west coast of the United States, and Yamaguti (1938) described *T. pseudorhombi* from *Pseudorhombus pentophthalmus*.

On the basis of the characters described for the genus by Yamaguti (1934) there can be no question that the hemiurids from the stomach of the scorpion fish, *Scorpaena madurensis* should be included in this group. The name *T. madurensis* Nigrelli (1939) was designated for this species and appears to be closely related to *T. pseudorhombi*. *T. madurensis* differs from

T. pseudorhombi in body size, size and extent of the seminal vesicle and *pars prostatica*, size and shape of the sinus sac, size, shape and extent of the vitellaria, amount of uterine coils and size of eggs.

The hemiurids comprise a large group of stomach parasites of marine fishes. As was pointed out by Looss (1907), Stunkard & Nigrelli (1934) and other investigators, these trematodes have powerful body muscles and are capable of contracting their body tremendously. Very great changes in the shape and spatial relations of the internal organs may be produced, especially when the caudal appendage is protruded or retracted. Comparisons between related worms should be made with care. Fortunately in this present group most of the worms described by the various authors were those with tail appendage fully extended and the following key could be employed to determine the recognized species.

KEY TO THE RECOGNIZED SPECIES OF *Tubulovesicula* YAMAGUTI, 1934.

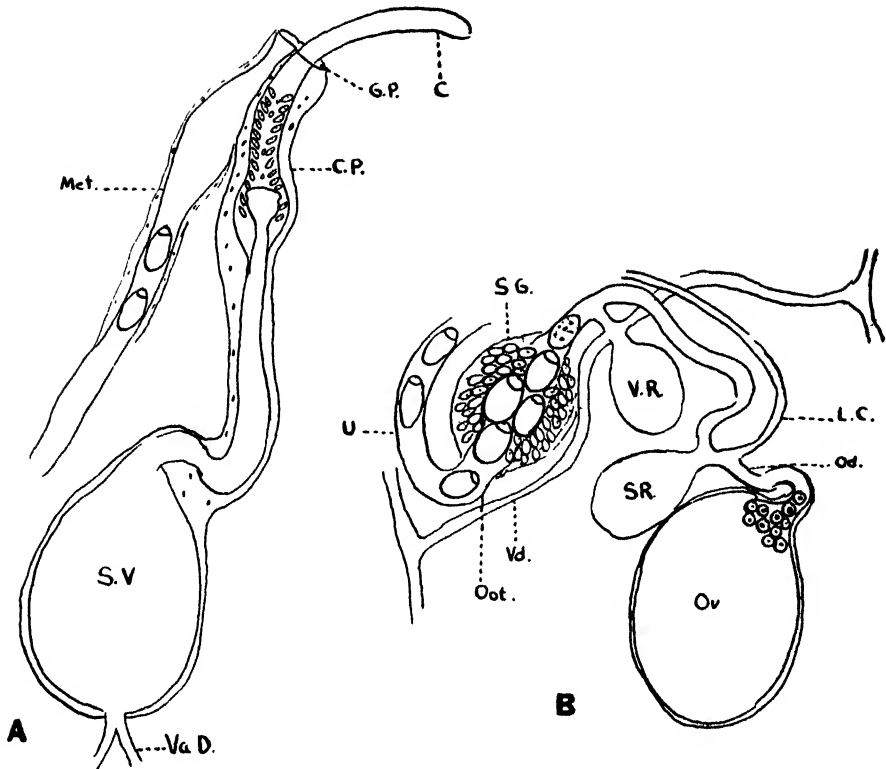
- A. Vitelline lobes 7 (3 + 4).
- B. Vitelline gland with three right and four left lobes.
- C. Uterine coils extending into tail for some distance.
- D. Seminal vesicle long and slender; tail shorter than body proper
T. spari Yamaguti, 1934 (Type sp.).
- DD. Seminal vesicle short and slender; tail longer than body proper
T. anguillae Yamaguti, 1934.
- E. Seminal vesicle long and broad.
- F. *Pars prostatica* originating at the middle of the acetabulum
T. muraenesocis Yamaguti, 1934.
- FF. *Pars prostatica* originating posterior to the acetabulum
T. lindbergi (Layman, 1930).
- EE. Seminal vesicle short and slender; *pars prostatica* originating at the level of the anterior border of the acetabulum
T. angusticauda (Nicoll, 1915).
- BB. Vitelline gland with four right and three left lobes.
- G. Seminal vesicle long and slender; *pars prostatica* originating at the level of the anterior border of the acetabulum
T. pseudorhombi Yamaguti, 1938.
- GG. Seminal vesicle short and broad; *pars prostatica* originating some distance posterior to the acetabulum
T. madurensis Nigrelli, 1939.
- AA. Vitelline lobes 8 (4 + 4)
T. californica Park, 1936.

***Podocotyle atzi*.**

(Plate I, Fig. 2; Text-figure 2).

The genus *Podocotyle*, according to Odhner (1906), is characterized as follows: "Body elongate, quite evenly wide, sometimes flattened and ribbon-like. Esophagus at most twice as long as pharynx, forking in front of the ventral sucker. Genital pore to the left, lying at the level of the esophagus. Excretory vesicle reaching to the ovary. Seminal vesicle long, coiled; *pars prostatica* lacking. Cirrus of marked length, straight. Ovary three-lobed. Vitellaria normally not reaching anterior to ventral sucker. Eggs without filament. In intestine of marine fish. Type species *P. atomon* (Rud.)."

Two worms were recovered from the intestine of *Scorpaena madurensis*, both measuring 4.41 mm. in length; width .707-.851 mm. Oral sucker .251 × .289 and .266 × .281 mm.; pharynx .205 × .167 and .190 × .152 mm.;



Text-figure 2.

Reproductive organs of *Podocotyle atzi*. **A.** Part of the terminal reproductive complex. C., cirrus; G.P. genital pore; C. P., cirrus pouch; Met., metraterm; S.V., seminal vesicle; Va. D., vas deferens. **B.** Ovarian complex. Ov., ovary; Od., oviduct; S. R., Seminal receptacle; L. C., Laurer's canal; V.R., vitelline reservoir; S.G., shell gland; Oot., ootype; Vd., vitelline duct; U., uterus.

esophagus $.294 \times .061$ mm.; ceca extending to the level of the posterior group of vitellaria; acetabulum, prominent, somewhat protruded, measuring $.519$ and $.590 \times .540$ mm. Testes sharply oblique, anterior testis $.255 \times .281$ mm. and $.296 \times .273$ mm.; posterior testis $.380 \times .243$ and $.327 \times .295$ mm. Ovary immediately in front of anterior testis, non-lobulated, measuring $.152 \times .190$ and $.203 \times .160$ mm. Seminal vesicle, slightly coiled, $.380 \times .167$ mm. and $.319 \times .152$ mm. Cirrus long and narrow, $.532 \times .053$ mm.; *pars prostatica* lacking; genital pore at the level of cecal bifurcation, to the left. Ovarian complex consisting of seminal receptacle, vitelline reservoir and shell gland. Laurer's canal present. Vitellaria mostly extra-testicular and extra-cecal, extending anteriorly to the level of the posterior border of the acetabulum and posteriorly to a short distance from the tip of the body. Uterine coils, intercecal, few, limited to area between the anterior border of the ovary and posterior border of the seminal vesicle. Eggs few, operculated, embryonated, measuring $.038 \times .062$. Excretory vesicle extending to level of the posterior testis and arms extending slightly anterior to the level of the bifurcation of the ceca, terminating on each side of the esophagus.

From the above description there can be no doubt that the allocreadids from the intestine of the Madeira scorpion fish belong to the genus *Podocotyle*. The present species designated as *P. atzi* Nigrelli (1939)

differs from other recognized species in body size, size of the eggs, esophagus-pharynx size relationships, size and relationships of the seminal vesicle, extent of the excretory branches, predominance of the acetabulum, shape of the ovary, and nature of the ovarian complex.

SUMMARY.

1. Two species of trematodes from the stomach and intestine of the Madeira scorpion fish, *Scorpaena madurensis*, are described.

2. The stomach parasites belong to the family Hemiuridae Lühe and were named *Tubulovesicula madurensis* by Nigrelli in 1939. The intestinal parasites belong to the family Allocreadiidae Stossich and were designated *Podocotyle atzi* by the same author.

3. A key to the species of *Tubulovesicula* Yamaguti (1934) is given.

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EXPLANATION OF THE PLATE.

Photographs made by direct projection of specimens on bromide paper.
Worms stained with Delafield's hematoxylin.

PLATE I.

Fig. 1. *Tubulovesicula madurensis*. $\times 22.7$.

Fig. 2. *Podocotyle atzi*. $\times 29$.

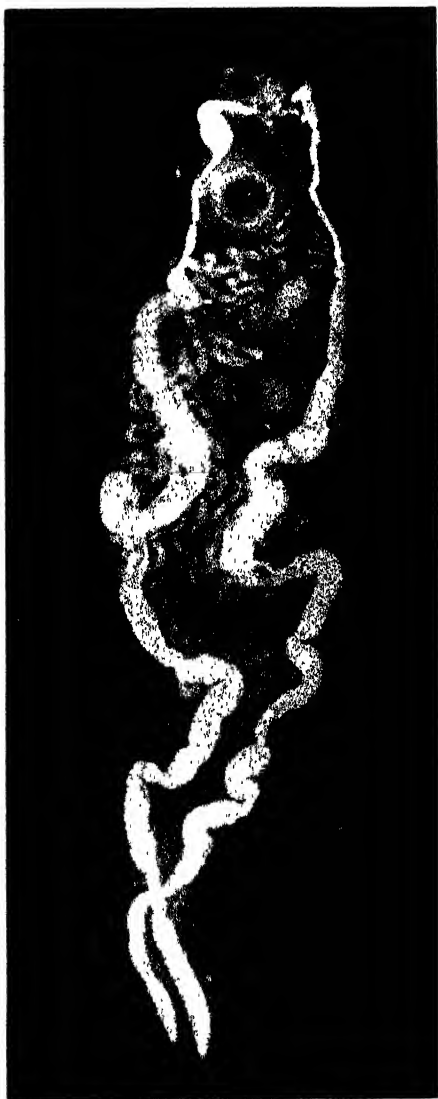


FIG. 1.

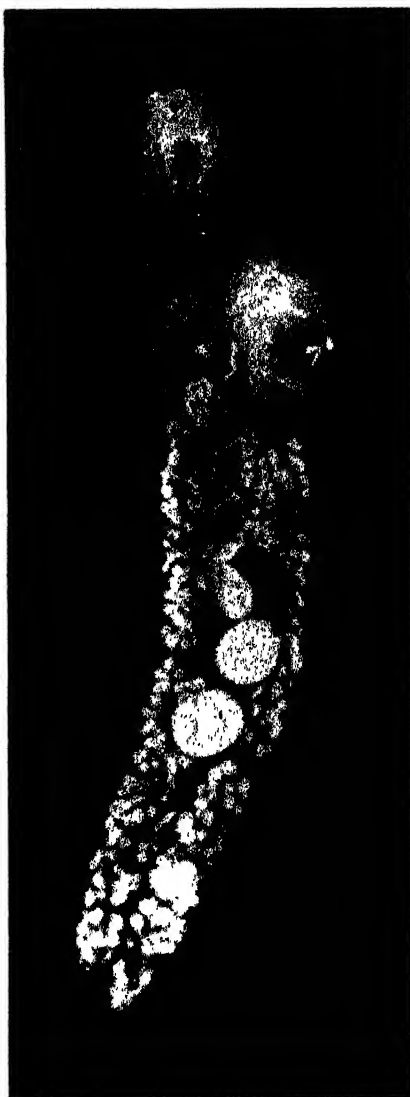


FIG. 2.

TWO NEW SPECIES OF TREMATODES FROM THE DEEP SEA
SCORPION FISH, *SCORPAENA MADURENSIS* CUV. & VAL

18.

Report of the Hospital and Laboratory of the New York Zoological Park, 1939. Mortality Statistics of the Society's Collection.

LEONARD J. GOSS

Veterinarian.

During the year 1939 autopsies were performed in the Hospital and Laboratory of the New York Zoological Park on 135 reptiles, 221 birds and 109 mammals which died in the Society's collection.

These figures do not represent the total number of deaths in the collection; they are merely the totals of specimens in each group which were subjected to post-mortem examination. Certain of the rarer mammals and birds, in particular, were deposited with the Department of Comparative Anatomy of the American Museum of Natural History without autopsy. Out of the 800 reptiles which died during the year, only a comparatively small number were examined. In the great majority of cases autolysis was advanced before the specimens reached the Laboratory.

As in the report of the Hospital and Laboratory for 1938, the titles of the International Classification of Causes of Death (human) have been employed, with such modification as was necessary to adapt them to the pathology of animals. Until a standard and generally accepted classification of the diseases of animals is compiled, a modification of the human disease list can bring at least a measure of uniformity into the reporting of animal mortality.

Joint or contributory causes of death have been ignored in the statistical summaries that follow, for the sake of brevity and clarity, and only the chief pathological changes found at autopsy have been reported. More detailed information is, of course, available on the autopsy records of the Hospital and Laboratory. These contain a description of both gross and microscopic tissue changes as well as the bacteriology and parasitology encountered at autopsy.

Grouping of specimens by age has been dropped except in the case of mammals where it was practicable to make distinctions between immature, adult and post-adult individuals. All birds and reptiles which came to autopsy were adult.

It should be stressed, in connection with Table V, that the specimens considered as "in the collection" during 1939 were, in some instances, of very brief tenure, and in many cases were never placed on exhibition. In some zoological collections it is the practice not to consider as "in the collection," for purposes of mortality statistics, specimens which failed to survive a minimum period which may range from thirty days to six months. The longer the probationary period, the lower the mortality percentage for the entire collection is likely to be. Table V includes some animals which arrived at the Zoological Park in a moribund state and failed to survive even their first day "in the collection."

TABLE I.

REPTILES.

	Specimens.	Total specimens autopsied.	Percentage of 135 reptiles autopsied.
INFECTIOUS & PARASITIC DISEASES		10	7.40
Acid-fast Infection		5	3.70
<i>Iguana i. rhinolopha</i> —Central American Iguana	3		
<i>Python m. molurus</i> —Black-tailed Python	1		
<i>Agkistrodon piscivorus</i> —Moccasin	1		
Intestinal Cestodes		3	2.22
<i>Farancia a. abacura</i> —Red-bellied Snake.....	1		
<i>Ptyas mucosus</i> —Indian Rat Snake	1		
<i>Agkistrodon blomhoffi</i> —Blomhoff's Pit Viper.....	1		
Intestinal Helminths		2	1.48
<i>Eunectes murinus</i> —Anaconda	1		
<i>Trimeresurus flavomaculatus</i> —Indian Green Tree Viper	1		
NUTRITIONAL DISEASES		4	2.96
Cachexia		4	2.96
<i>Iguana i. rhinolopha</i> —Central American Iguana.....	2		
<i>Farancia a. abacura</i> —Red-bellied Snake.....	1		
<i>Vipera russelii</i> —Russell's Viper.....	1		
DISEASES OF CIRCULATORY SYSTEM		3	2.22
Endocarditis with Ruptured Myocardium		1	.74
<i>Lampropeltis getulus floridana</i> —Florida King Snake..	1		
Pericarditis		1	.74
<i>Python m. molurus</i> —Black-tailed Python.....	1		
Filariasis with Ruptured Myocardium		1	.74
<i>Lampropeltis getulus</i> subsp.—Texas King Snake.....	1		
DISEASES OF RESPIRATORY SYSTEM		34	25.18
Pneumonia		34	25.18
<i>Zonurus giganteus</i> —Spike-tailed Lizard.....	1		
<i>Constrictor c. constrictor</i> —South American Boa.....	2		
<i>Python curtus</i> —Blood Python.....	1		
<i>Python reticulatus</i> —Regal Python.....	1		
<i>Arizona e. elegans</i> —Smooth-scaled Gopher Snake.....	1		
<i>Boiga dendrophila</i> —Malay Mangrove Snake.....	2		
<i>Drymarchon corais couperi</i> —Texas Gopher Snake.....	1		
<i>Elaphe q. quadrivittata</i> —Chicken Snake.....	2		
<i>Pituophis s. sayi</i> —Prairie Bull Snake.....	1		
<i>Ptyas mucosus</i> —Indian Rat Snake.....	1		
<i>Dendroaspis angusticeps</i> —Black Mamba.....	1		
<i>Dendroaspis viridis</i> —Green Mamba.....	1		
<i>Naja naja</i> —Indian Cobra.....	2		
<i>Naja nivea</i> —Yellow Cobra.....	1		
<i>Trimeresurus flavomaculatus</i> —Indian Green Tree Viper	1		
<i>Cerastes cerastes</i> —Desert Asp.....	1		
<i>Agkistrodon mokasen cupreus</i> —Copperhead.....	1		
<i>Agkistrodon piscivorus</i> —Moccasin	5		
<i>Crotalus a. atrox</i> —Texas Diamond Rattlesnake.....	5		
<i>Crotalus v. viridis</i> —Prairie Rattlesnake.....	1		
<i>Crotalus horridus atricaudatus</i> —Canebrake Rattlesnake	1		
<i>Crotalus h. horridus</i> —Banded Rattlesnake.....	1		
DISEASES OF DIGESTIVE SYSTEM		63	46.66
Hepatitis		3	2.22
<i>Iguana i. rhinolopha</i> —Central American Iguana.....	1		
<i>Python reticulatus</i> —Regal Python.....	1		
<i>Dendroaspis viridis</i> —Green Mamba.....	1		

TABLE I. (Continued)

REPTILES.			Specimens.	Total specimens autopsied.	Percentage of 135 reptiles autopsied.
Necrotic Stomatitis				6	4.44
<i>Heloderma horridum</i> —Mexican Beaded Lizard.....			1		
<i>Boa canina</i> —Green Tree Boa.....			1		
<i>Python curtus</i> —Blood Python.....			1		
<i>Python regius</i> —Ball Python.....			1		
<i>Naja naja</i> —Indian Cobra.....			1		
<i>Vipera russelii</i> —Russell's Viper.....			1		
Enteritis				13	9.62
<i>Varanus</i> sp.—Monitor Lizard.....			1		
<i>Elaphe g. quadrivittata</i> —Chicken Snake.....			1		
<i>Lampropeltis getulus splendida</i> —Mexican King Snake..			1		
<i>Pituophis m. melanoleucus</i> —Pine Snake.....			1		
<i>Pituophis s. sayi</i> —Prairie Bull Snake.....			1		
<i>Cerastes cerastes</i> —Desert Asp.....			1		
<i>Agkistrodon mokasen cupreus</i> —Copperhead.....			1		
<i>Crotalus a. atrox</i> —Texas Diamond Rattlesnake.....			4		
<i>Crotalus h. horridus</i> —Banded Rattlesnake.....			2		
Necrotic Enteritis				41	30.37
<i>Ctenosaura acanthura</i> —Black Iguana.....			1		
<i>Heloderma suspectum</i> —Gila Monster.....			1		
<i>Tupinambis teguixin</i> —Tegu Lizard.....			1		
<i>Boa canina</i> —Green Tree Boa.....			9		
<i>Constrictor c. constrictor</i> —South American Boa.....			3		
<i>Epicrates cenchris</i> —Ringed Boa.....			2		
<i>Eunectes murinus</i> —Anaconda.....			1		
<i>Python curtus</i> —Blood Python.....			1		
<i>Python m. molurus</i> —Black-tailed Python.....			3		
<i>Python regius</i> —Ball Python.....			1		
<i>Python reticulatus</i> —Regal Python.....			1		
<i>Boiga dendrophila</i> —Malay Mangrove Snake.....			1		
<i>Drymarchon corais couperi</i> —Texas Gopher Snake.....			1		
<i>Lampropeltis g. getulus</i> —Common King Snake.....			1		
<i>Dendroaspis viridis</i> —Green Mamba.....			1		
<i>Naja hannah</i> —King Cobra.....			1		
<i>Naja naja</i> —Indian Cobra.....			1		
<i>Bitis gabonica</i> —Gaboona Viper.....			1		
<i>Vipera russelii</i> —Russell's Viper.....			1		
<i>Agkistrodon piscivorus</i> —Moccasin.....			1		
<i>Crotalus a. atrox</i> —Texas Diamond Rattlesnake.....			5		
<i>Crotalus cerastes</i> —Horned Rattlesnake.....			1		
<i>Crotalus h. horridus</i> —Banded Rattlesnake.....			2		
DISEASES OF SKIN & CELLULAR TISSUE				5	3.70
Abscess				2	1.48
<i>Drymarchon c. corais</i> —Cribro Rat Snake.....			1		
<i>Agkistrodon piscivorus</i> —Moccasin.....			1		
Dermatitis				3	2.22
<i>Python regius</i> —Ball Python.....			2		
<i>Agkistrodon piscivorus</i> —Moccasin.....			1		
UNDETERMINED DIAGNOSIS				16	11.85

TABLE II.

BIRDS.			Specimens.	Total specimens autopsied.	Percentage of 135 reptiles autopsied.
INFECTIOUS & PARASITIC DISEASES.....				24	10.85
Salmonella Infection				2	.90
Coliuspasser a. albonotatus—White-shouldered Whydah	1				
Tangara arthus—Yellow-throated Calliste.....	1				
Tuberculosis				10	4.52
Anas crecca carolinensis—American Green-winged Teal	1				
Meleagris gallopavo silvestris—Eastern Turkey.....	1				
Porphyrio poliocephalus poliocephalus — Gray-headed Gallinule	1				
Streptopelia d. decacoto—Barbary Turtle Dove.....	6				
Melozona leucotis—White-eared Ground Sparrow.....	1				
Aspergillosis				3	1.35
Guttera e. edouardi—Black-breasted Crested Guinea-fowl	1				
Amazona ventralis—Santo Domingo Amazon.....	1				
Chlorophonia f. frontalis—Yellow-fronted Green Tanager	1				
Liver Flukes				2	.90
Ardea goliath—Goliath Heron.....	1				
Florida caerulea—Little Blue Heron.....	1				
Coccidiosis				2	.90
Astrapia s. stephaniae—Princess Stephanie's Bird of Paradise	1				
Tangara heinei—Black-capped Calliste.....	1				
Intestinal Obstruction—Nematodes				1	.45
Columba livia—Swallow Pigeon.....	1				
Taeniasis				4	1.80
Ostinops viridis—Great Green Cacique.....	1				
Tangara cyaneicollis hannahiae—Blue-throated Calliste	1				
Tangara heinei—Black-capped Calliste.....	1				
Turdus m. merula—European Blackbird.....	1				
NUTRITIONAL DISEASES				2	.90
Slipped Tendon Disease (Manganese Deficiency).....				1	.45
Casmerodius albus egretta—American Egret.....	1				
Malnutrition				1	.45
Tyto alba pratincola—American Barn Owl.....	1				
DISEASES OF CIRCULATORY SYSTEM.....				6	2.71
Atheromatosis				6	2.71
Amazona ochrocephala oratrix—Yellow-headed Amazon	1				
Bubo v. virginianus—Horned Owl.....	1				
Anthracoceros m. malabaricus—Indian Pied Hornbill..	1				
Eucyanistes cristatus—Silver-cheeked Hornbill.....	1				
Rhyticeros subruficollis—Blyth's Wreath-billed Hornbill	1				
Ramphastos piscivorus brevicarinatus — Short-billed Toucan	1				
DISEASES OF RESPIRATORY SYSTEM.....				23	10.40
Ulcerative Laryngitis				6	2.71
Ajaia ajaja—Roseate Spoonbill.....	1				
Sagittarius serpentarius—Secretary Bird.....	1				
Pucrasia m. macrolopha—Common Koklass Pheasant...	1				
Amazona b. barbadensis—Yellow-shouldered Amazon..	1				
Amazona ochrocephala panamensis—Panama Amazon..	1				
Brachypternus benghalensis benghalensis — Northern Golden-backed Woodpecker	1				

TABLE II. (Continued)

BIRDS.			Specimens.	Total specimens autopsied.	Percentage of 135 reptiles autopsied.
Tracheitis				1	.45
<i>Belonopterus chilensis lamprenotus</i> —Argentine Lapwing			1		
Pulmonary Congestion				1	.45
<i>Agelaius ruficapillus frontalis</i> —Chestnut-fronted Black-bird			1		
Pneumonia				15	6.78
<i>Tragopan caboti</i> —Cabot Tragopan			1		
<i>Ptilinopus jambu</i> —Jambu Fruit Pigeon			1		
<i>Crinifer piscator</i> —Brown-headed Touraco			1		
<i>Agapornis</i> sp.—Masked Love Bird			1		
<i>Anodorhynchus leari</i> —Lear's Macaw			1		
<i>Brotheria j. jugularis</i> —Tovi Parrakeet			1		
<i>Tyto alba pratincola</i> —American Barn Owl			1		
<i>Anthracothonax v. violicauda</i> — Black-throated Mango Hummingbird			1		
<i>Chlorostilbon caribaeus caribaeus</i> —Caribbean Emerald Hummingbird			1		
<i>Pharomachrus m. mocinno</i> —Quetzal			1		
<i>Amblyrhaphus holosericeus</i> —Orange-headed Blackbird			1		
<i>Carpodacus mexicanus frontalis</i> —Western House Finch			1		
<i>Tangara m. mexicana</i> —Yellow-bellied Calliste			1		
<i>Parotia l. lawesi</i> —Lawes' Six-plumed Bird of Paradise			1		
<i>Uraeginthus b. bengalus</i> —Cordon Bleu			1		
DISEASES OF DIGESTIVE SYSTEM				31	14.02
Impacted Crop				1	.45
<i>Gallus g. gallus</i> —Red Jungle Fowl			1		
Gizzard Impaction				4	1.80
<i>Plectropterus gambensis niger</i> — Black Spur-winged Goose			1		
<i>Buteo jamaicensis borealis</i> —Eastern Red-tailed Hawk			1		
<i>Circus cyaneus hudsonius</i> —Marsh Hawk			1		
<i>Urobrachya a. axillaris</i> —Orange-shouldered Whydah			1		
Enteritis				13	5.88
<i>Casmerodius albus egretta</i> —American Egret			1		
<i>Ciconia c. ciconia</i> —European White Stork			1		
<i>Cygnus olor</i> —Mute (White) Swan			1		
<i>Crossoptilon mantchuricum</i> —Brown Eared Pheasant			1		
<i>Amazona f. festiva</i> —Festive Amazon			1		
<i>Psittacus e. erithacus</i> —Gray Parrot			1		
<i>Larus argentatus smithsonianus</i> —Herring Gull			1		
<i>Chlorophonia f. frontalis</i> —Yellow-fronted Green Tanager			1		
<i>Paradisaea gulielmi</i> —Emperor of Germany's Bird of Paradise			1		
<i>Tangara cyanoptera</i> —Blue-winged Calliste			1		
<i>Tangara flava cayana</i> —Black-faced Calliste			1		
<i>Tangara larvata centralis</i> —Mrs. Wilson's Calliste			1		
<i>Tanagra v. violacea</i> —Violet Euphonia			1		
Cirrhosis of Liver				1	.45
<i>Lophura rufa</i> —Malayan Crested Fireback Pheasant			1		
Hepatitis				11	4.97
<i>Rhynchotus jubatus</i> —Kagu			1		
<i>Bycanistes sharpii duboisi</i> —Congo White-tailed Hornbill			1		
<i>Ramphastos swainsonii</i> —Swainson's Toucan			1		
<i>Euplectes f. franciscana</i> —Orange Weaver			1		

TABLE II. (Continued)

BIRDS.			Specimens.	Total specimens autopsied.	Percentage of 135 reptiles autopsied.
<i>Munia a. atricapilla</i> —Black-headed Mannikin.....	1				
<i>Notiopsar curaeus</i> —Chilean Blackbird.....	1				
<i>Paroaria nigrigenis</i> —Black-cheeked Cardinal.....	1				
<i>Rubigula dispar</i> —Sumatran Ruby-throated Bulbul.....	1				
<i>Spinus t. tristis</i> —American Gold Finch.....	1				
<i>Thraupis c. cana</i> —Southern Blue Tanager.....	1				
<i>Turdus o. olivaceus</i> —Olive Thrush.....	1				
Icterus		1			.45
<i>Aidemossyne m. modesta</i> —Cherry Finch.....	1				
DISEASES OF GENITO-URINARY SYSTEM				9	4.07
Nephritis				8	3.61
<i>Dissoura episcopus microscelis</i> —African White-necked Stork.....	1				
<i>Theristicus caudatus</i> —Guiana Ibis.....	1				
<i>Psittacula eupatria nipalensis</i> —Indian Ring Parrakeet.....	1				
<i>Nymphicus hollandicus</i> —Cockateel.....	1				
<i>Musophaga v. violacea</i> —Senegal Violet Touraco.....	1				
<i>Gymnoderus foetidus</i> —Bare-necked Cotinga.....	1				
<i>Kittocinclia m. malabarica</i> —Shama Thrush.....	2				
Egg Bound		1			.45
<i>Phasianus colchicus versicolor</i> —Versicolor Pheasant... ..	1				
DISEASES OF SKIN & CELLULAR TISSUE				4	1.80
Abscess				4	1.80
<i>Lophortyx c. californica</i> —California Quail.....	1				
<i>Pavo cristatus</i> var.—White Indian Peafowl.....	1				
<i>Kakatoe r. roseicapilla</i> —Roseate Cockatoo.....	1				
<i>Pitta sordida cucullata</i> —Green-breasted Pitta.....	1				
VIOLENT & ACCIDENTAL DEATHS				71	32.12
Trauma—Head				37	16.74
<i>Argusianus argus argus</i> —Great Argus Pheasant.....	1				
<i>Chrysolophus pictus</i> —Golden Pheasant.....	1				
<i>Gennaeus leucomelanos melanotus</i> —Melanotus Pheasant.....	1				
<i>Philortyx fasciatus</i> —Banded Quail.....	1				
<i>Anthropoides paradisea</i> —Paradise Crane.....	1				
<i>Larus atricilla</i> —North American Laughing Gull.....	1				
<i>Larus n. novae-hollandiae</i> —Silver Gull.....	1				
<i>Leptotila c. cassini</i> —Cassin Dove.....	1				
<i>Streptopelia d. decaocto</i> —Barbary Turtle Dove.....	1				
<i>Kakatoe g. galerita</i> —Greater Sulphur-crested Cockatoo.....	1				
<i>Kakatoe r. roseicapilla</i> —Roseate Cockatoo.....	1				
<i>Kakatoe sanguinea goffini</i> —Goffin's Cockatoo.....	1				
<i>Melopsittacus undulatus</i> —Grass Parrakeet.....	2				
<i>Pionites m. melanocephala</i> —Black-headed Caique.....	1				
<i>Trichoglossus haematod moluccanus</i> —Blue Mountain Lorikeet.....	1				
<i>Ramphastos discolorus</i> —Green-billed Toucan.....	1				
<i>Megalaima virens marshallorum</i> —Great Himalayan Barbet.....	1				
<i>Auripasser luteus</i> —Abyssinian Golden Sparrow.....	1				
<i>Tangara icterocephala</i> —Silver-throated Calliste.....	1				
<i>Chlorophonia f. frontalis</i> —Yellow-fronted Green Tanager.....	1				
<i>Corvus b. brachyrhynchos</i> —Eastern Crow.....	1				

TABLE II. (Continued)

BIRDS.	Specimens.	Total specimens autopsied.	Percentage of 135 reptiles autopsied.
<i>Cyanerpes cyaneus</i> —Yellow-winged Sugar Bird.....	2		
<i>Euplectes f. franciscana</i> —Orange Weaver.....	1		
<i>Euplectes o. orix</i> —Grenadier Weaver.....	1		
<i>Hemixus f. flavala</i> —White-throated Bulbul.....	1		
<i>Myadestes unicolor</i> —Blue Solitaire.....	1		
<i>Padda oryzivora</i> —Java Sparrow.....	1		
<i>Ramphocelus c. carbo</i> —Silver-beaked Tanager.....	1		
<i>Taeniopygia c. castanotis</i> —Zebra Finch.....	1		
<i>Tangara flava cayana</i> —Black-faced Calliste.....	2		
<i>Tangara g. guttata</i> —Larger Spotted Calliste.....	3		
<i>Tanagra xanthogaster exsul</i> —Venezuelan Rufous-capped Euphonia.....	1		
Fractured Cervical Vertebrae		1	.45
<i>Rhynchotus rufescens rufescens</i> —Rufous Tinamou.....	1		
Fractured Tibia & Fibula		1	.45
<i>Grus canadensis tabida</i> —Sandhill Crane.....	1		
Destroyed—Fractured Humerus		1	.45
<i>Pavo cristatus</i> —Peacock.....	1		
Destroyed—Blind		1	.45
<i>Dromiceius n. novaehollandiae</i> —Emu.....	1		
Drowning		1	.45
<i>Ploceus v. vitellinus</i> —Half-masked Weaver.....	1		
Poisoning—Botulism		29	13.12
<i>Aix sponsa</i> —Wood Duck.....	3		
<i>Anas platyrhynchos</i> —White Duck.....	1		
<i>Anas p. platyrhynchos</i> —Mallard Duck.....	19		
<i>Anas rubripes tristis</i> —Black Duck.....	1		
<i>Chen caerulescens</i> —Blue Goose.....	1		
<i>Cygnus olor</i> —Mute Swan.....	1		
<i>Dendrocygna a. autumnalis</i> —Black-breasted Tree Duck.....	2		
<i>Dendrocygna autumnalis discolor</i> —Gray-breasted Tree Duck.....	1		
DIAGNOSIS UNDETERMINED		51	23.07

TABLE III.

MAMMALS.	Immature.	Adult.	Post-adult.	Total specimens autopsied.	Percentage of 109 mammals autopsied.
INFECTIOUS & PARASITIC DISEASES	3	6	1	10	9.17
Tuberculosis		3	1	4	3.66
<i>Cebus capucina</i> —White-faced Sapajou.....		1			
<i>Cercocebus torquatus</i> —Red-headed Man-gabey.....		1			
<i>Macaca irus</i> —Java Macaque.....			1		
<i>Macaca mulatta</i> —Rhesus Monkey.....		1			
Infectious Feline Enteritis	3			3	2.75
<i>Acinonyx jubatus</i> —Cheetah.....	1				
<i>Felis cougar</i> —Puma.....	1				
<i>Felis pardalis</i> —Ocelot.....	1				
Acanthocephaliasis		1		1	.91
<i>Solenodon paradoxus</i> —Solenodon.....		1			
Ascariidiasis		1		1	.91
<i>Didelphis virginiana</i> —Opossum.....		1			
Trichinosis		1		1	.91
<i>Taxidea taxus taxus</i> —American Badger*....		1			
CANCER AND OTHER TUMORS		2	1	3	2.75
Carcinoma Esophagus		1		1	.91
<i>Tragelaphus angasi</i> —Nyala.....		1			
Liver Cell Carcinoma		1		1	.91
<i>Odocoileus osceola</i> —Florida White-tailed Deer.....		1			
Osteogenic Sarcoma			1	1	.91
<i>Cervus axis</i> —Axis Deer.....			1		
NUTRITIONAL DISEASES	4	2		6	5.50
Malnutrition	4	2		6	5.50
<i>Cebus capucina</i> —White-faced Sapajou....	1				
<i>Cercopithecus mona cambelli</i> —Mona Monkey.....	1				
<i>Cercopithecus sabaeus</i> —Green Monkey....		1			
<i>Hapale pygmaea</i> —Pygmy Marmoset.....		1			
<i>Cervus canadensis canadensis</i> —Elk.....	1				
<i>Hemitragus jemlahicus</i> —Tahr.....	1				
DISEASES OF BLOOD & BLOOD PRODUCING ORGANS.		1		1	.91
Anemia		1		1	
<i>Nasua nasua</i> —White-nosed Coati.....		1			
DISEASES OF NERVOUS SYSTEM		8		8	7.33
Encephalitis		4		4	3.66
<i>Ateles cucullatus</i> —Spider Monkey.....		1			
<i>Macaca nemestrina</i> —Pigtail Monkey.....		1			
<i>Papio anubis</i> —Olive Baboon.....		2			
Destroyed—Facial Paralysis		1		1	.91
<i>Cebus capucina</i> —White-faced Sapajou....		1			
Destroyed—Posterior Paralysis				1	.91
<i>Sarcophilus harrissii</i> —Tasmanian Devil....		1			
Destroyed—Blindness		2		2	1.83
<i>Acinonyx jubatus</i> —Cheetah.....		2			
DISEASES OF CIRCULATORY SYSTEM		1	1	2	1.83
Vegetative Endocarditis		1	1	2	1.83
<i>Didelphis virginiana</i> —Opossum.....			1		
<i>Mephitis nigra</i> —Skunk.....		1			

TABLE III. (Continued)

MAMMALS.	Immature.	Adult.	Post-adult.	Total specimens autopsied.	Percentage of 109 mammals autopsied.
DISEASES OF RESPIRATORY SYSTEM	9	11	1	21	18.34
Suppurative Sinusitis		1		1	.91
<i>Lutra canadensis vaga</i> —Florida Otter.....		1			
Pulmonary Congestion & Edema	8	2	1	11	10.09
<i>Macaca irus</i> —Java Macaque.....	1				
<i>Macaca mulatta</i> —Rhesus Monkey.....	1				
<i>Erithizon d. dorsatum</i> —Canadian Porcupine.....		1			
<i>Lutra canadensis vaga</i> —Florida Otter.....	2	1			
<i>Choeropsis liberiensis</i> — Pygmy Hippopotamus	1				
<i>Cervus eldi</i> —Eld's Deer.....	1				
<i>Ammotragus lervia</i> —Aoudad	2				
<i>Saiga tatarica</i> —Saiga Antelope.....			1		
Bronchopneumonia	1	7		8	7.33
<i>Callithrix penicillata</i> —Marmoset		1			
<i>Ateles cucullatus</i> —Spider Monkey.....	1				
<i>Lagothrix humboldtii</i> —Woolly Monkey....		1			
<i>Cercopithecus mona cambelli</i> —Mona Monkey.....		1			
<i>Zalophus californianus</i> —Sea Lion.....		1			
<i>Euphractus sexcinctus</i> —Six-banded Armadillo		1			
<i>Procavia capensis</i> —Hyrax		1			
<i>Dama dama</i> —Fallow Deer.....		1			
Gangrenous Pneumonia		1		1	.91
<i>Arctocephalus australis</i> — South American Fur Seal		1			
DISEASES OF DIGESTIVE SYSTEM	3	12	2	17	15.59
Choke		1		1	.91
<i>Suricata suricatta</i> —Meerkat		1			
Gastro-enteritis	2	8		10	9.17
<i>Lagothrix infumatus</i> —Woolly Monkey.....		3			
<i>Papio anubis</i> —Olive Baboon.....		1			
<i>Didelphis virginiana</i> —Opossum	1				
<i>Phastolomis mitchelli</i> —Wombat		1			
<i>Macropus g. giganteus</i> —Great Gray Kangaroo		1			
<i>Ursus a. arctos</i> —European Brown Bear....		1			
<i>Cervus unicolor</i> —Indian Sambar Deer.....		1			
<i>Cervus hortulorum</i> —Dybowski Deer	1				
Volvulus of Intestines		1		1	.91
<i>Odocoileus osceola</i> — Florida White-tailed Deer		1			
Impaction of Colon with Ulceration	1			1	.91
<i>Didelphis virginiana</i> —Opossum	1				
Actinobacillosis—Oral Tissues		2		2	1.83
<i>Sylvicapra grimmii</i> —Gray Duiker.....		2			
Enteritis—Squill Poisoning			1	1	.91
<i>Koiropotamus koiropotamus kenlac</i> — Gray Bush Pig			1		
Icterus		1		1	.91
<i>Lutra canadensis vaga</i> —Florida Otter.....			1		
DISEASE OF BONES & ORGANS OF LOCOMOTION ...	2			3	2.75
Paget's Disease			1	1	.91
<i>Papio anubis</i> —Olive Baboon.....	1				

TABLE III. (Continued)

MAMMALS.	Immature.	Adult.	Post-adult.	Total specimens autopsied.	Percentage of 109 mammals autopsied.
Muscular Dystrophy		2		2	1.83
<i>Dendrolagus ursinus</i> —Tree Kangaroo.....		2			
CONGENITAL MALFORMATION	1			1	.91
Congenital Anomaly—Legs	1			1	.91
<i>Cervus axis</i> —Axis Deer	1				
DISEASES OF NEW BORN	1			1	.91
Internal Hemorrhage—Umbilical Artery	1			1	.91
<i>Lama vicugna</i> —Vicugna	1				
SENILITY			5	5	4.58
Destroyed—Senility			5	5	4.58
<i>Didelphis virginiana</i> —Opossum			1		
<i>Camelus dromedarius</i> —Dromedary			2		
<i>Cervus duvauceli</i> —Barasingha Deer			1		
<i>Cervus canadensis canadensis</i> —Elk.....			1		
VIOLENT AND ACCIDENTAL DEATHS	8	10	1	19	17.43
Destroyed—Trauma	8	10	1	19	17.43
<i>Cebus capucina</i> —White-faced Sapajou.....	1	1			
<i>Erythrocebus patas</i> —Patas Monkey.....	1				
<i>Macaca irus</i> —Java Macaque.....	1				
<i>Didelphis virginiana</i> —Opossum			1		
<i>Potos flavus</i> —Kinkajou		1			
<i>Canis latrans</i> —Coyote		1			
<i>Felis cacomitli</i> —Jaguarundi Cat.....		1			
<i>Felis leo</i> —Lion	1				
<i>Paradoxurus hemaphroditus</i> —Yellow Para-					
doxure	3				
<i>Dasypus novemcinctus texanus</i> — Nine-					
banded Armadillo		1			
<i>Dama dama</i> —Fallow Deer		2			
<i>Odocoileus osceola</i> — Florida White-tailed					
Deer		2			
<i>Ammotragus lervia</i> —Aoudad	1	1			
DIAGNOSIS UNDETERMINED	5	7		12	11.00

* Reported in *Jour. of Parasit.*, April, 1940, Vol. 26, No. 2, page 157.

TABLE IV.
Summary of Mortality Percentage in Specimens Autopsied,
by Disease Groups.

Disease Group	% of 135 Reptiles	% of 221 Birds	% of 109 Mammals
Gastro-intestinal	46.66	14.02	15.59
Respiratory	25.18	10.40	18.34
Nutritional	2.96	.90	5.50
Infectious and Parasitic.....	7.40	10.85	9.17
Trauma .....	....	16.74	17.43
All Other Causes.....	17.80	47.09	33.97

TABLE V.
Summary of Mortality for All Specimens in the Collection
During 1939.

	Reptiles	Birds	Mammals
Specimens in Collection During 1939 ¹ ...	1,246	2,105	621
Deaths from All Causes ²	800	415	120
% of Mortality in Collection ³	64.20	19.71	19.32

¹ These figures represent the number of specimens that came into, or remained in, the Park during 1939, and are the totals of specimens in the collection in the course of the year. Some died before being placed on exhibition.

² Includes all deaths irrespective of cause or time after arrival.

³ Based on total specimens and total deaths.

19.

Eastern Pacific Expeditions of the New York
Zoological Society. XX.
Medusae of the Templeton Crocker and Eastern Pacific *Zaca*
Expeditions, 1936-1938.¹

HENRY B. BIGELOW

Museum of Comparative Zoology, Harvard University.

(Text-figures 1-20).

[This is the twentieth of a series of papers dealing with the collections of the Eastern Pacific Expeditions of the New York Zoological Society made under the direction of William Beebe. The present paper is concerned with specimens taken on the Templeton Crocker (1936) and Eastern Pacific *Zaca* (1937-1938) Expeditions. For data on localities, dates, nets, etc., refer to *Zoologica*, Vol. XXII, No. 2, pp. 33-46, and Vol. XXIII, No. 14, pp. 287-298.]

CONTENTS.

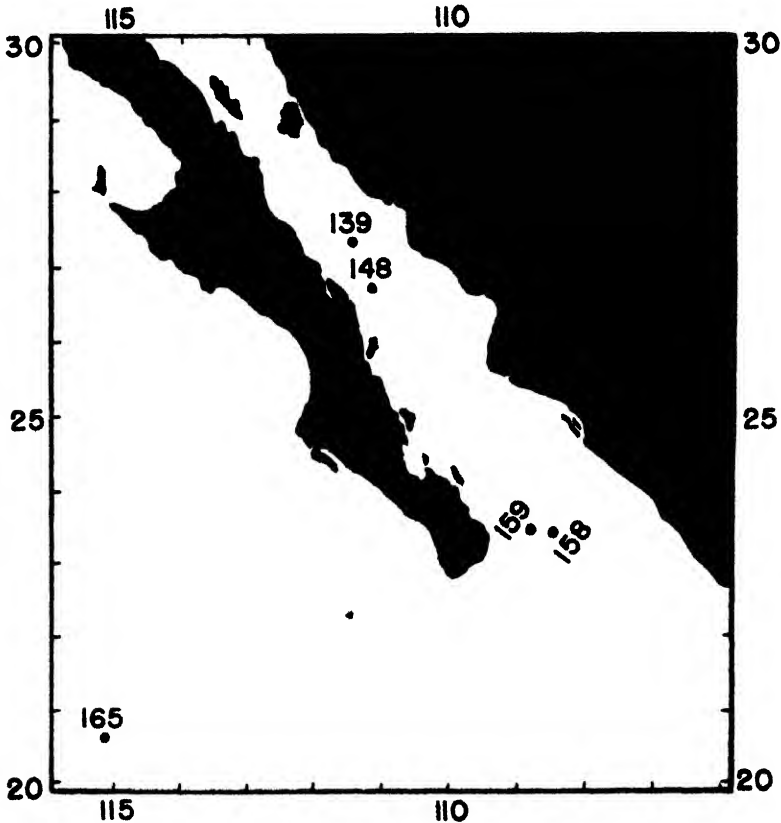
	Page.		Page.
Introduction	282	<i>Colobonema</i>	302
Hydromedusae		<i>Colobonema typicum</i> Maas	302
Anthomedusae	282	Halieridae	302
Pandidae	282	<i>Halieras</i>	302
<i>Stomatoca</i>	282	<i>Halieras minimum</i> Fewkes	302
<i>Stomatoca pterophylla</i> Haeckel	283	Narcomedusae	303
<i>Leuckartiara</i>	284	Solmaridae	303
<i>Leuckartiara zaca</i> sp. nov.	284	<i>Pegantha</i>	305
<i>Neoturia</i>	287	<i>Pegantha clara</i> R. P. Bigelow	305
<i>Neoturia crockeri</i> sp. nov.	287	? <i>Pegantha martagon</i> Haeckel	308
<i>Calycopsis</i>	290	<i>Solmissus</i>	308
<i>Calycopsis simulans</i> Bigelow	293	<i>Solmissus marshalli</i> Agassiz & Mayer	308
Bougainvilliidae	294	Aeginidae	309
<i>Chiarella</i>	294	<i>Aeginura</i>	309
<i>Chiarella centripetalis</i> Maas	294	<i>Aeginura beebei</i> sp. nov.	309
Leptomedusae	296	<i>Aeginura grimaldii</i> Maas	313
Thaumantidae	296	<i>Aegina</i>	313
<i>Polyorchis</i>	296	<i>Aegina citrea</i> Eschscholtz	313
<i>Polyorchis penicillata</i> Eschscholtz	296	Scyphomedusae	314
Laodiceidae	297	Coronata	314
<i>Chromatonema</i>	297	Periphyllidae	314
<i>Chromatonema erythronon</i> Bigelow	297	<i>Periphylla</i>	314
Aequoridae	299	<i>Periphylla hyacinthina</i> Steenstrup	314
<i>Zygocanna</i>	299	Atollidae	315
<i>Zygocanna vagans</i> Bigelow	299	<i>Atolla</i>	315
Trachomedusae	302	<i>Atolla wyvillei</i> Haeckel	315
Geryonidae	302	Discophora	315
<i>Liriope</i>	302	Pelagidae	315
<i>Liriope tetraphylla</i> Chamisso &		<i>Pelagia</i>	315
Eysenhardt	302	<i>Pelagia noctiluca</i> Forskål	315
Trachynemidae	302	Stomolophidae	316
		<i>Stomolophus</i>	316
		<i>Stomolophus meleagris</i> L. Agassiz	316

¹ Contribution No. 601, Department of Tropical Research, New York Zoological Society.
Contribution No. 239 of the Woods Hole Oceanographic Institution.

INTRODUCTION.

The medusae described in the following pages were collected by Dr. William Beebe on Mr. Templeton Crocker's Yacht *Zaca*, off Lower California and in the Gulf of California in April-May, 1936, and along the Pacific coast of Central America from Costa Rica to Panama in February-April, 1938. For data of the stations where medusae were taken on the first of these cruises (Stas. 139-165), see Beebe (1937); for those of the second cruise (Stas. 210-284), Beebe (1938).

The locations of the stations are shown on Text-figs. 1 and 2.



Text-fig. 1.

Locations of stations 139-158, April, 1936.

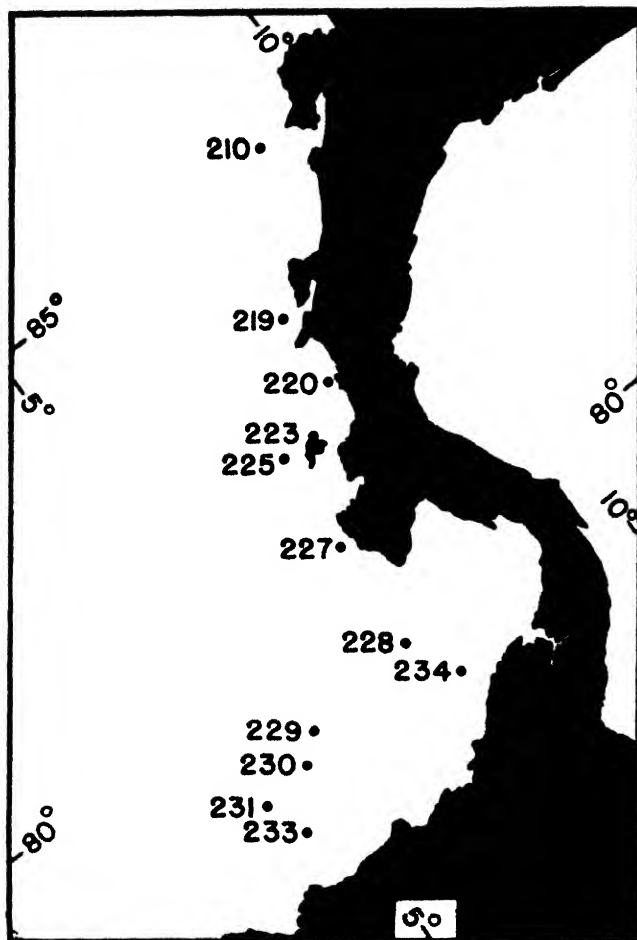
HYDROMEDUSAE.

ANTHOMEDUSAE.

Pandeidae.

Stomotoca.

Differences of opinion still exist as to whether the pandeids with only two large opposed tentacles, but many rudimentary tentacles, represent two genera, one with gelatinous peduncle (*Stomotoca*), the other without (*Amphinema*), or whether they properly form but a single genus, to which the name *Stomotoca* must be applied, on the grounds of priority. The latter



Text-fig. 2.
Locations of stations 210-234, February-April, 1938.

viewpoint has recently been adopted by Uchida (1927) and by Ling (1937), following Mayer (1910). To Hartlaub (1914), however, among others, to Russell (1938), and to me (1909, 1918), the presence or absence of a peduncle has seemed a character of generic importance, and is so considered here.

Stomotoca pterophylla Haeckel.

Stomotoca pterophylla, Haeckel, 1879, p. 52, Pl. 4, Fig. 10. For subsequent references and discussions, see Bigelow, 1918, p. 372; Ranson, 1936, p. 63.

Material: Sta. 229, surface, 1 specimen about 20 mm. in diameter: Sta. 231, surface, 1 specimen about 22 mm. in diameter, both in moderately good condition.

Comparison of series from the Florida-Bahaman region and from the Eastern Tropical Pacific has failed to reveal any significant difference between the Pacific *divisa* and the Atlantic *pterophylla* (Bigelow, 1918, p. 370); and this conclusion the present examples corroborate, for they agree in all significant respects with Maas' (1897) account of "*S. divisa*" from the Gulf of Panama, and with the *Albatross* series reported by me under that name

from the vicinity of the Galápagos and from the West coast of Mexico (Bigelow, 1909).

Records for the compound species in the Pacific are confined to the vicinity of the Galápagos, and along the west coast of America from southern Mexico to Colombia. In the Atlantic, however, its range appears to be more extensive, for it has been taken not only near Florida and the Bahamas in the western side (Haeckel, 1879; Mayer, 1910; Bigelow, 1918), but also in the central basin (Ranson, 1936).²

Leuckartiara.

Leuckartiara zacae sp. nov.

Text-figs. 3-5.

Material: Sta. 227, 910-0 meters, one specimen about 21 mm. high by 18 mm. in diameter, somewhat shrivelled in preservation, but otherwise in fair condition.

In 1916, Browne described, from the Indian Ocean, an interesting new pandeid (*Leuckartiara gardineri*), the generic identity of which was established by the structure of its gonads, but which differed from all known representatives of *Leuckartiara* in the presence of exumbral nematocyst-ribs extending upward over the surface of the bell from the bases of the tentacles. This character it shares with *Pandea conica* and with *Eutiara mayeri*, the gonads of which are, however, very different.

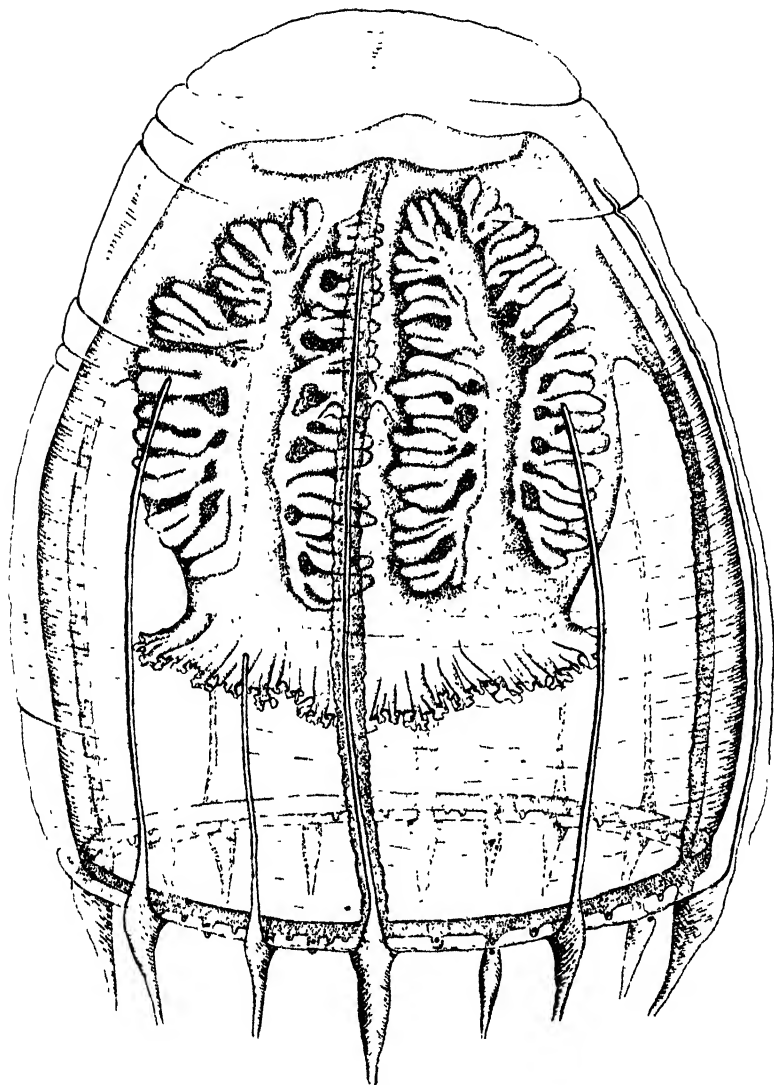
The present specimen, similarly referable to *Leuckartiara* by its gonads, recalls *gardineri* in the presence of exumbral ribs. And (so far as can be judged in optical section) these ribs, like those of *gardineri* and of *Eutiara mayeri* (Bigelow, 1918, p. 375), are canalar extensions of the tentacular bases, whereas in *Pandea conica*, Hartlaub (1913, p. 336) describes them as simply thickenings of the ectoderm. It differs, however, from *gardineri* in the following respects:

1. *Number of tentacles:* In the unique specimen of *gardineri*, there were only four large (perradial) tentacles and in addition about 24 rudimentary knobs, some with filaments, but others lacking the latter. And since the gonads contained fairly well-advanced ova, it seems probable that four is the final number of large tentacles in that form. In the *Zaca* specimen, however, there are (besides the four perradials) two or three other well-developed tentacles of different sizes per quadrant (a total of fifteen), each with corresponding exumbral rib, and also 1-3 rudimentary knobs (lacking filaments) between every two tentacles (Text-fig. 3).

2. *Number and length of exumbral ribs:* In Browne's specimen of *gardineri* there were four of these, one opposite each perradial tentacle and extending nearly to the apex of the bell. In the present example, in addition to the four perradials, there are 2, 1, 1 and 1 others in the different quadrants, or a total of nine, each connected with a tentacle. And while four of the smaller tentacles lack them, exumbral ribs might later have developed in connection with these also. On the other hand, even the perradial ribs reach up only about $\frac{2}{3}$ of the height of the bell, i.e., to about the level where the radial canals arise from the manubrial wall, while the others reach only to about the mid-level of the bell.

3. *Gonads:* These are considerably more complex than in *gardineri*, there being 8-12 primary folds, which bifurcate or trifurcate in each adradial series, as against 4-5 primary folds only—each bifid—per adradial series in *gardineri*. In *gardineri*, furthermore, the adradial series are united in

² Ranson (1936, p. 64) states that the Monaco specimen was collected "au sud des Açores." But the position of the station in question (Monaco, Station 2115) is given as Lat. 31° 42' N., long. 42° 40' W., or roughly midway between the Azores and Bermuda.



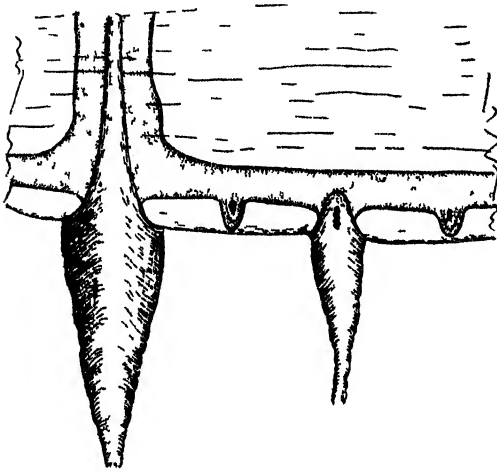
Text-fig. 3.

Leuckartiara zaca, sp. nov., type specimen, slightly restored.

each quadrant, by a transverse fold at about the mid-level of the manubrium (Browne, 1918, Pl. 39, Fig. 4), but this commissure is evident in one quadrant only of the *Zaca* specimen, suggesting that its presence represents a transitory stage in development. The specimen is apparently a male; at least no ova are visible in surface view.

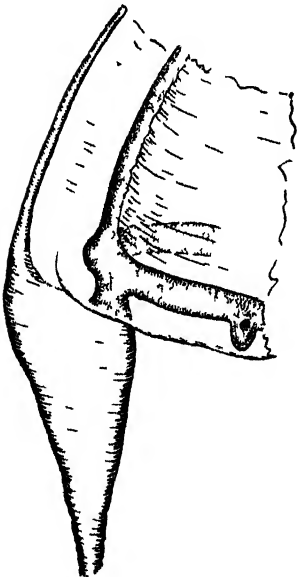
Evaluation of these differences depends on whether the new-found specimen represents merely an advanced stage in the growth of a known species (all the differences being of a progressive sort), or whether it is a distinct species which, in its growth, passes through a stage in which it closely resembles the known form, but which attains to a greater degree of morphological complexity before reaching maturity. In the present instance, the available bases for decision are conflicting, for while the *Zaca*

specimen is about six times as large as the type of *gardineri* (suggesting an advanced stage in growth), the localities of capture for the two are on opposite sides of the globe. And since it seems important to emphasize the differences rather than to minimize them, so that the matter will be more searchingly examined by whomever is lucky enough to obtain additional specimens, a new specific name is proposed for the medusa under discussion here.



Text-fig. 4.

Leuckartiara zacae, sp. nov.,
margin with large and small
tentacles, camera drawing, about
× 14.



Text-fig. 5.

Leuckartiara zacae, sp. nov., lateral view
of radial tentacle with nematocyst rib, about
× 15.

Further points worth notice are that the tentacular bulbs are laterally flattened, clasping the exumbrella (as is usual in this genus), and that the tentacular knobs, as well as such of the fully formed tentacles as still lack exumbral prolongations, bear pigment spots on their abaxial sides. But the spots ("ocelli") are lacking on the tentacles in connection with which exumbral ribs have developed—apparently they are lost when the latter structures appear. The edges of the notably broad radial canals are slightly wavy; those of the ring canal smooth.

The ocelli are brick red, the manubrium and tentacular bulbs a pale salmon-color after preservation, which suggests a more brilliant reddish or pinkish hue in life.

Neoturris.

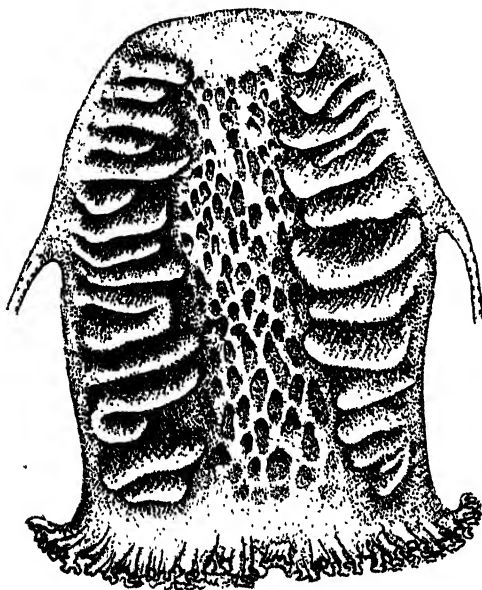
***Neoturris crockeri* sp. nov.**

(Text-figs. 6-10).

Material: Sta. 234, 910-0 meters, 1 fragmentary specimen about 28 mm. high by about 32 mm. in diameter.

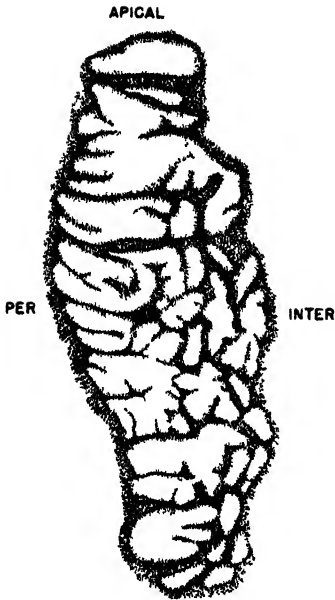
The unique example is so badly battered that reconstruction of the general form of the bell can be only tentative, further than that it is thin-walled throughout, without apical thickening, and apparently slightly broader than high. Fortunately, however, (though now in fragments) it still shows the chief anatomical characters.

At first glance, the specimen might easily be mistaken for a *Pandea rubra*, thanks to its dark chocolate-red pigmentation (see below). However, the structure of the gonads is quite different, being clearly of the "*Neoturris*" type as defined by Hartlaub (1914). More precisely, each perradial belt is flanked, on either hand, by a series of transverse folds of various sizes (Text-fig. 6). As is typical of *Neoturris*, the sexual folds are not connected one with another at their interradian ends, but are entirely independent. But the interradian zone of the manubrial wall, between each two series of folds, is occupied by a series of small irregular ridges—primarily longitudinal—alternating with recesses. Comparison of Text-fig. 6 with Hartlaub's (1914, p. 35, Fig. 273) picture of the manubrium of *N. pileata* will show the essential similarity. However, while the adradial folds are simple in one of the quadrants (Text-fig. 6), in another adjacent (Text-fig. 7) they are so complexly split and cross-furrowed that it is impossible either to distinguish between primary folds and secondary, or even, in the extreme case, to distinguish sharply where adradial folds give place to interradian mesh-work. Locally, then, the "*Neoturris*" state grades into the "*Pandea*" state. Nowhere, however, does it grade into the "*Leuckartiara*" state, i.e., that in



Text-fig. 6.

Neoturris crockeri, sp. nov.,
interradian view of one quadrant
of manubrium to show gonads,
somewhat restored.



Text-fig. 7.

Neoturris crockeri, sp. nov., adradial series of sexual folds in quadrant adjacent to that shown in Text-fig. 6. Camera drawing.

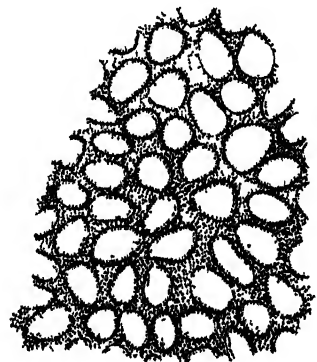
which the interrarial extremes of the transverse adradial folds are connected. The specimen is a female, the sex folds packed with large eggs (Text-fig. 8)—and scattered eggs are to be seen in the interrarial belts, as well. It is interesting, as an example of a fate that no doubt causes an appreciable destruction of medusan eggs, that in the present case a considerable number are to be seen within the radial canals.

The relationship of radial canals to manubrium is of the type characteristic of the more complexly organized pandeids (*Neoturris*, *Pandea*, *Leuckartiara*, *Catablema*), for the so-called "mesenteries" are so well developed (Text-fig. 6) that the canals depart from the manubrium at about the mid-level of the latter. Above this level, consequently, the bell cavity is subdivided into four extensive pockets by the lines of attachment between the manubrium and subumbrella.

The canals themselves are broad, flat (as usual in this family), their edges nearly smooth—or at most but slightly irregular. And this applies equally to the margin of the ring canal. The manubrium occupies the greater part of the bell cavity, hanging in its present state about to the level of the bell opening. The lips are complexly crenulated, much as in *Pandea rubra*.

Text-fig. 8.

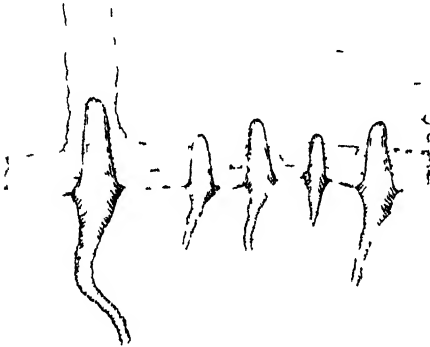
Neoturris crockeri, sp. nov., portion of one of the sexual folds packed with ova, camera drawing, $\times 60$.



There are 38 tentacles, the numbers in successive quadrants being 10, 9, 9, 10, of various sizes (Text-fig. 9). Presumably this would have been the final number in this particular specimen, for there are no additional rudiments or knobs. The tentacle bases, broadly triangular in side view (Text-fig. 10), and laterally compressed, clasp the exumbrella, as is so commonly the case in this family, and taper gradually to slender filaments.

There is no trace of exumbrel ridges connected with the tentacles. And since the surface of part, at least, of the bell is in fair condition, there is no reason to suppose that such structures were present in life, but had been destroyed. Neither are any ocelli to be seen.

The most interesting feature of this specimen is its bathypelagic coloration, the manubrium as a whole being of a dense reddish-chocolate hue, paling at the lip, and with the opaque white eggs showing through the overlying, pigmented ectoderm, much as do the larger eggs of the *Narcomedusa*, *Aeginura grimaldii*. The bases of the tentacles and a narrow peripheral belt of the subumbrella are sparsely pigmented with the same hue, the pigment granules in the latter cases so large and loosely spaced as to be individually visible under low magnification. The remainder of the subumbrella is faintly tinged, though without visible granules.



Text-fig. 9.

Neoturris crockeri, sp. nov.,
segment of margin to show the
tentacles of different sizes,
about $\times 7.5$.

Superficially, as noted above, this specimen most resembles *Pandea rubra* among known pandeids. However, the tentacles are considerably more numerous, the maximum yet recorded for a considerably larger specimen of *rubra* being only 20 (Bigelow, 1938, p. 107). More important, the structure of the gonads proves that the resemblance to *Pandea rubra* is only super-

Text-fig. 10.

Neoturris crockeri, sp. nov., lateral view of
one of the medium-sized tentacles.



ficial and that we are actually dealing with a *Neoturris*. However, it differs from all known pandeids in which the gonads are definitely known to be of the "*Neoturris*" type, not only in its peculiar pigmentation, but also in the facts that the radial canals are smooth-edged, and that the tentacular organs, large or small, are so few in number and consequently so widely spaced. A new species seems therefore necessary for its reception.

The depth of capture of the type (and so far only known) specimen (910-0) argues, as does its color, that it is a member of the bathypelagion.

Calycopsis.

Up to the present time, eleven supposed species have been referred to this genus or to *Sibogita*, now generally considered synonymous with it. The necessity of decision as to the status of its representative in the *Zaca* collection makes this an opportune time to summarize the features by which the several named members of the genus have been separated one from another. Critical revision (depending on the evaluation of variability) must, however, await the accumulation of larger study series.

One of the species, *birulai* Linko (1913), can be omitted from the discussion, on the ground that it does not belong to this genus, but is more closely allied to *Eumedusa similis* (Bigelow, 1920). It may, in fact, prove identical with the latter, in which case Linko's specific name would take precedence.

For the remaining members of *Calycopsis*, the following characters have been chiefly emphasized as specific: 1, number of tentacles and canals and their interrelationship; 2, arrangement of centripetal canals and the degree to which these finally fuse either with one another, with the radials, or with the base of the manubrium; 3, morphology of the gonads; 4, presence or absence of labial nematocyst knobs; 5, whether or not the radial canals are dilated at their points of emergence from the manubrium to form so-called "mesenteries"; 6, presence or absence of gelatinous exumbrellar papillae on the marginal lobes of the bell; and 7, presence or absence of a funnel-shaped apical exumbrellar depression. Among these characters, the presence of an apical depression in *typa*, of labial nettle knobs in *nematophora*, and of prominent papillae on the exumbrellar surfaces of the marginal lobes in *papillata*, in *valdiviae*, and in at least one of the specimens in the collection of the German South Polar Expedition (taken near the Cape Verdes), that were recorded by Vanhöffen (1912) as "*typa*," contrasted with their absence elsewhere, is strictly alternative. The presence or absence of subumbrellar muscle bands along the radii of the tentacles, and of pigment spots at the bases of the tentacles, also appears to be alternative at least between certain of the named forms. Similarly, the conformation of the gonads is of two rather sharply opposed types, for while in *borchgrevinkii* (at least in the male), the sex products develop in pockets of the manubrial wall, and open to the exterior by small pores (Browne, 1910; Vanhöffen, 1911, p. 216, Fig. 10a; Mackintosh, 1934), the gonads of all other known members of the genus form double rows of transverse folds, occupying the interradial sectors of the manubrium, the minor divergences being that in *nematophora*, small irregular folds occur between the chief series, and that in *typa*, the gonads bear egg-shaped swellings, scattered here and there (Bigelow, 1909a, Figs. 1, 2).

Other characters are less sharply discontinuous. Thus, *chuni* with 36-27 canals, *geometrica* with 32-22, *typa* with 21-16, and *nematophora* with 18-16 form a continuous series. In *valdiviae*, however, the number of canals recorded (60) is some 20 greater than in any other known *Calycopsis*; in *bigelowi* and in *simplex*, it may be permanently smaller (8). In *simulans* and in *papillata*, the number (12 in each case) appears to be determinate,

probably also in *borchgrevinki* (16), whereas in most, at least, of the other supposed species it is variable. In *simulans* and *papillata*, furthermore, the centripetal canals are all adradial, whereas in all other named forms in which the metameral arrangement has been determined, there is an inter-radial canal in each quadrant with or without adradials according to the number of centripetals peculiar to the particular species in question. In this respect, *typha* is especially unstable for there may be 2, 3, or 4 canals in adjoining quadrants (Bigelow, 1909a), beside the interradian member. Ordinarily the centripetals arise singly from the ring canal. In *typha*, however, they may exceptionally arise in pairs (Bigelow, 1909a, Fig. 7), while in *chuni* they may be either single or in groups of two or three (Vanhöffen, 1911, p. 218, Pl. 22, Fig. 8).

In previous discussions of the genus, much emphasis has been laid on the endings of the centripetal canals, i.e., whether permanently blind, or whether finally fused with the radial canals, or with the cruciform base of the manubrium. In *bigelowi*, in *simplex*, and in such of the specimens recorded as *typha* as seem properly to have belonged to that species, the canals are described as ending blindly—in the latter case even in a specimen 37 mm. high with large ova (Bigelow, 1909a, p. 290). In *simulans* and *valdiviae* some at least join the base of the manubrium, but others (by present indications) may remain permanently blind, which according to Browne (1910, p. 17) also applies to *borchgrevinki*. In *nematophora* all come finally to join the base of the manubrium—a junction interpretable in some cases as with a radial canal at its point of origin from the manubrium (Bigelow, 1913, Pl. 3, Fig. 24). In *papillata* they all end blindly in medium-sized specimens, but in the largest (27 mm. high, with eggs), two were still blind, “but of the remaining six, three have joined the cruciform base of the manubrium; two join radial canals close to their bases, and one joins a radial canal at a considerable distance from the manubrium” (Bigelow, 1918, p. 280, Pl. 2, Fig. 1). This specimen thus bridges the gap between the foregoing group and *geometrica*, in which all the centripetals unite with the radials at different levels.

The numbers of tentacles in the different members of *Calycopsis* overlap to a greater degree than do the numbers of canals, the total range (60-8) being practically covered by three species, *nematophora* (57-30), *typha* (30-16), and *borchgrevinki* (8-16). Recorded numbers of tentacles for the other supposed species are: *valdiviae*, about 60; *bigelowi*, 48; *chuni*, 16-17; *geometrica*, 16-22; *simulans*, 12-18; *papillata*, 12; *simplex*, 8.

As appears from the foregoing, the canals and tentacles may be equal in number (a tentacle opposite every canal); they may be either equal in number or the tentacles the more numerous (*simulans*); the tentacles may be characteristically the more numerous (*borchgrevinki*, *bigelowi*, *nematophora*, *typha*); or the canals the more numerous (*geometrica*, *chuni*).

In *typha*, it appears that the tentacles develop before the corresponding canals appear; apparently also in *nematomorpha*, hence this is likely the general rule, except in forms in which the final number of canals is greater than that of the tentacles.

Taxonomic evaluation of labial knobs and of gonad-structure presents no difficulty, for these both appear of full specific import. Thus, *nematomorpha* is set apart from all other members of the genus by the presence of the former, as well as by the presence of subumbbral muscle bands along the canalar radii; *borchgrevinki* by the gonads. The presence of a well-marked apical exumbbral depression, coupled with an evident tendency for the centripetal canals to continue blind, even at maturity, is a good mark of identification for *typha*, for while the depression might seem a trivial feature, its presence, not only in Fewkes' (1882) original specimen, but also in others collected many years later by the *Grampus*, and in five more in the

Arcturus collection (all from the same general region off the northeast coast of the United States) seems to establish its constancy.

Geometrica is equally marked off by one outstanding character, i.e., by the union (in the adult) of all the centripetal canals with the radials. The only other *Calyropsis* that at all approaches it in this respect (*papillata*) has well marked exumbral sculpture which *geometrica* lacks.

Simulans and *typa* form a natural group so far as general appearance is concerned—so closely, in fact, do they resemble each other that Vanhöffen (1911) classed the former as a synonym of the latter. However, all the specimens referable to *simulans* that have so far been seen (including the *Zaca* specimen described below) have differed from typical *typa* not only in lacking any trace of apical depression, or of the egg-shaped swellings on the gonads that appear characteristic of the latter, but also in the fact that for them the number of canals appears to be determinate (12) instead of variable. Among the examples of "*simulans*" so far recorded, one from the Philippines (Bigelow, 1919) is set apart by the facts that most of the centripetal canals are fused with the manubrium instead of ending blindly, and that there are eight small tentacles in addition to the twelve that correspond to the canals. Whether this represents a geographic variation—i.e., that development progresses further in this respect in one race of *simulans* than in another—or whether the Philippine example actually belongs to some form as yet unnamed, is a question for the future.

Chuni, to judge from Vanhöffen's (1911, Pl. 22, Fig. 8) picture, must be grouped in its general organization with the *typa-simulans* group. However, its canals (27, 36) are somewhat more than twice as numerous as its tentacles (16, 17), whereas in *typa* and in *simulans*, the tentacles are at least as numerous as the canals. *Valdiviae* (to judge from the only adult yet seen) is set apart by the very large number (60) of canals, just commented upon, combined with absence of mesenteries. In *bigelowi* the numerical ratio of tentacles (48, large and small) to canals (8) is much larger than in any other member of the genus. And while the small size of the one specimen so far seen (only 12 mm. high) might suggest that it was a juvenile, the well-developed gonads argue against this view. Vanhöffen's (1911, p. 218, Fig. 12) illustration also suggests that part of the tentacles remain permanently small. *Simplex*, finally, while agreeing with *bigelowi* and *borchgrevinki* in the small number (8) of canals, is separated from the former by the fact that it has only about $\frac{1}{6}$ as many tentacles (8), and from the latter by the structure of the gonads. It may be the juvenile of some other form.

It appears, in short, that while the various named members of the genus are closely allied, one to another, most, at least, of them differ sufficiently to be accepted as good species until intermediates be actually found. Their geographic distribution tends to strengthen this conclusion. Thus, specimens with apical depression (*typa*) have been taken only off the continental slope of North America; those agreeing with the original specimens of *simulans* only off the west coast of Central America; those with labial nematocyst knobs (*nematomorpha*) only in the Bering Sea region; those with the *borchgrevinki* type of gonads only in high southern latitudes; those with the *geometrica* type of canalization are known only in the Philippines and East Indies; the *simplex* type only from Norway; those of the *bigelowi* and *chuni* types from the Gulf of Aden.

Specimens with warty marginal lobes have, it is true, been recorded widespread, i.e., from the Florida-Bahamas region (*papillata*, Bigelow, 1918), from the vicinity of the Cape Verde Islands (Vanhöffen, 1912), and from the Alghulas current by Vanhöffen (1911) as "*typa*," this last being the specimen on which Hartlaub (1914) subsequently founded the species *valdiviae*. But *papillata* and *valdiviae* differ so widely in other respects (as

emphasized above) that there can be no question of their identity. And the description of the other warty specimens recorded by Vanhöffen (1912, as "*typha*"³), classed tentatively by Hartlaub (1914) as juveniles of *valdiviae*, are not detailed enough for positive identification.

The following artificial key to the species of *Calycopsis* may be helpful for purposes of identification:

1. With labial nettle knobs and subumbbral muscle bands
nematophora Bigelow
 Without labial nettle knobs or subumbbral muscle bands 2
2. All centripetal canals join the radial canals at various levels
geometrica Maas
 Most of the centripetal canals either end blindly, or join the cruciform base of the manubrium 3
3. With about 60 canals at maturity *valdiviae* Hartlaub
 With 40 canals, or fewer 4
4. Gonads in pockets *borchgrevinki* Browne
 Gonads in exterior folds 5
5. Exumbrella with well-marked apical depression *typha* Fewkes
 Without apical depression 6
6. Many more canals than tentacles *chuni* Vanhöffen
 Tentacles at least as numerous as canals 7
7. Marginal lobes with well-marked exumbbral papillae *papillata* Bigelow
 Marginal lobes smooth or nearly so 8
8. Many more tentacles than canals *bigelowi* Vanhöffen
 Number of tentacles and canals about equal 9
9. Centripetal canals all adradial *simulans* Bigelow
 Centripetal canals interradiial *simplex* Kramp & Damas

***Calycopsis simulans* Bigelow.**

Sibogita simulans, Bigelow, 1909, p. 213, Pl. 5, Figs. 4, 5; Pl. 41, Figs. 8, 9; Pl. 43, Figs. 1, 2; 1913, p. 21; Mayer, 1910, p. 187.

Calycopsis simulans, Hartlaub, 1913, p. 360; Bigelow, 1918, p. 377.

Calycopsis typha (Partim), Vanhöffen, 1911, p. 214.

? *Calycopsis typha* var. *simulans*, Bigelow, 1919, p. 292, Pl. 40, Fig. 8; Pl. 41, Fig. 1.

Material: Sta. 233, 910-0 meters, one specimen, in good condition, about 26 mm. high by 25 mm. broad.

The *Zaca* capture corroborates the evidence afforded by the two specimens from between Panama and the Galápagos, for which the species was originally established, that the final number of canals in *simulans* is 12, i.e., 2 centripetals in each quadrant. In the original specimens these all ended blindly, though in their growth they had reached nearly to the cruciform base of the manubrium⁴. And this is true also of the *Zaca* specimen, though in this case the canalar terminations come so close to the manubrium that careful examination was required to demonstrate the discontinuity. It also agrees with the type specimen in the presence of as many large tentacles (12) as canals, one of the former opposite each of the latter. The fact that specimens apparently adult (to judge from the gonads) from

³ Among three juveniles recorded as *typha*, two from the tropical Atlantic and one from the Indian Ocean, Vanhöffen (1911, p. 364) states that the wartiness was especially prominent after alcoholic preservation, which identifies the specimens as above.

⁴ As pointed out elsewhere (Bigelow, 1913, p. 23), it is probable that a specimen from Bering Sea originally referred by me to *simulans*, in which the canals all join the manubrium (Bigelow, 1909, p. 214, Fig. 2), actually belonged to *C. nematomorpha*.

the same general region, but taken 32 years apart, agree so closely in these respects makes it likely that this is the final state. And for this reason it may finally prove necessary to find a new name for the Philippine specimen, originally described by me (1919) as var. *simulans* of *typa*, but in which all but one of the centripetals had already fused with the manubrium though the medusa was only 16 mm. in diameter, and in which there were eight small tentacles, besides the twelve larger ones connected with the canals (p. 292).

I need only note further that the tentacles, like those of the original specimens—of most other members of the genus, in fact—are tipped with prominent nematocyst knobs; that the sexual folds correspond closely to those of the type in regularity and general arrangement, and that there is no trace either of an apical depression or of exumbrial papillae on the marginal lobes.

In the preserved condition the manubrium is pale ochre, the tentacles colorless.

The fact that the *Albatross* specimens were taken at the surface makes it likely that the present example was picked up by the net at a small depth, either on its way down, or its way up.

Bougainvilliidae.

Chiarella.

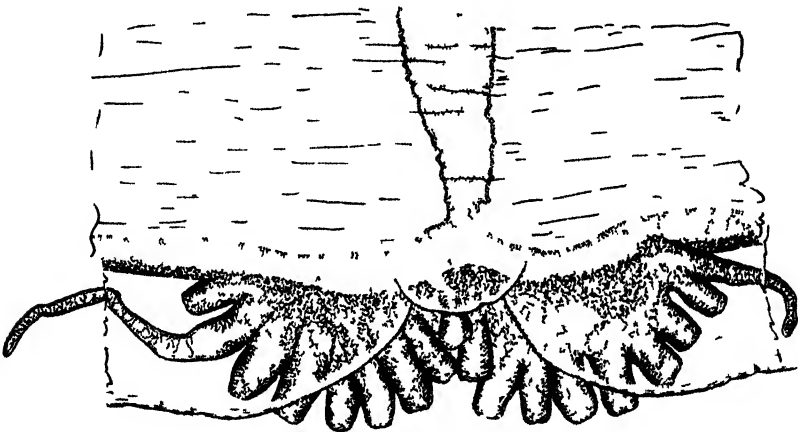
Chiarella centripetalis Maas.

(Text-figs. 11, 12).

Chiarella centripetalis, Maas, 1897, p. 15, Pl. 2, Figs. 1-4; 1905, p. 13; Mayer, 1910, p. 182; Foerster, 1923, p. 29.

Material: Stas. 139, 148, 159, in hauls respectively from 549-0, 549-0, 910-0 meters, 5 specimens, about 20-25 mm. high.

This large and easily recognized species had not been reported since originally described by Maas (1897) from specimens taken in the Gulf of California in 1891 by the U. S. Fish Commission Steamer *Albatross*. The



Text-fig. 11.

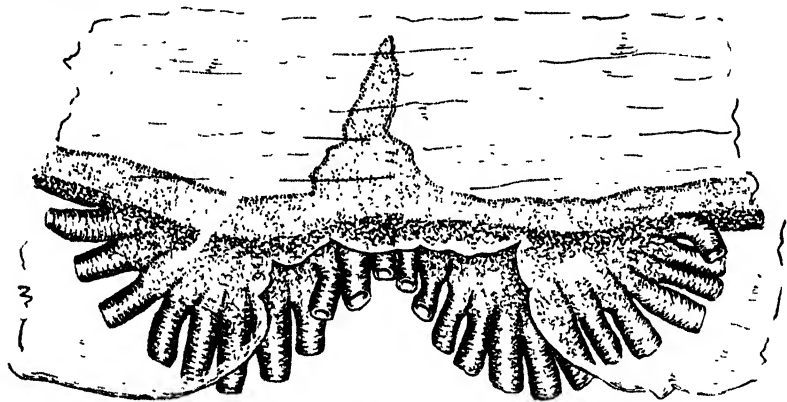
Chiarella centripetalis Maas, from Sta. 159, radial group of tentacles, camera drawing, about $\times 13$.

Zaca captures in the same general region are, therefore, of considerable geographic interest.

The specimens, though all more or less damaged, are in good enough condition to show that in most respects they agree with Maas' account so closely that there is no doubt of their specific identity. This applies, in particular, to the general form of the bell; to the outlines and lengths of the spur-like interradial centripetal canals (Text-fig. 12), to the conformation of the gonads and to the basic arrangement of the eight groups of tentacles, by which the genus is characterized. Conspicuous, in particular, is the epaulette-shape of the basal folds from which the tentacular filaments arise (Text-figs. 11, 12), and the adradial series of transverse sex folds in the manubrial wall, which, in two of the *Zaca* specimens, are packed with large eggs.

The peduncle is considerably longer in four of the five *Zaca* specimens (the condition of the fifth is not good enough to show this) than in Maas' (1897) illustration based on a sketch from life, occupying in the extreme case, about $\frac{1}{3}$ of the length of the bell cavity. But as there is a considerable variation in this respect within the series, and as all of them are in a flaccid condition in weak formalin, it is probable that this apparent difference between the collections of 1891 and of 1936 is the result either of different states of contraction or of preservation.

It is also worth mention that the margins of the radial canals (at least in the better-preserved examples) are slightly irregular or wavy though never definitely lobed—a feature not mentioned by Maas. The ring canal is smooth-edged.



Text-fig. 12.

Chiarella centripetalis Maas from Sta. 139, interradial group of tentacles, camera drawing, about $\times 16$.

According to Maas (1897, p. 16) there are about as many tentacles in the interradial groups as in the radials (more than 40 in each, a total of more than 320). However, he does not state whether an individual count was made of any group other than the one pictured. And the *Zaca* series proves not only to be more variable in this respect, but with the number averaging only about half as great in specimens of the same size, the numbers being as follows for the groups for which counts are possible:

APPROXIMATE BELL HEIGHT	RADIAL GROUPS	INTERRADIAL GROUPS
24 mm.	19, 19, 20, 18	16, 16, 17, 19
23 mm.	18, 19	16, 25
21 mm.	22, 22±, 25±, 33±	24, 23, 31, 38±
20 mm.	23±, 24±, 24±	28±, 27±, 24, 24±
25 mm.	not more than 20 in any group	

The spacing around the bell margin is also variable, for while in the 24 mm. and 25 mm. specimens, all the epaulettes are approximately equal in breadth and of approximately the same breadth as the interspaces, in the 21 mm. specimen the interradial group with 38 tentacles occupies practically the entire interspace between the two adjacent radial groups.

Maas remarked that "die einzelnen Fäden sind verhältnissmässig kurz, was nicht auf Rechnung ihrer Contraction zu setzen ist, wie Skizzen nach dem Leben zeigen" (Maas, 1897, p. 16). Similarly, in the *Zaca* series all the more central members of each group are not only mere stumps (Text-figs. 11, 12) but such of them as are in good condition are rounded at the ends. But in several of the better-preserved groups the one or two tentacles near the outer margin extend as well developed though short filaments (Text-fig. 11), suggesting that all the tentacles may have been extensible to at least this extent in life.

According to Maas there is an ocellus at the base of each tentacle, as also appears in his color sketch from fresh material (Maas, 1897, Pl. 2, Fig. 1). These are not visible on the *Zaca* specimens, but they may have faded in the preservative.

In the preserved state the manubrium varies between dull salmon-pink and ochre yellow; the tentacular pads are of various shades of reddish-yellow.

The original account includes no information as to the depth of capture. But the fact that all of the *Zaca* specimens were taken in hauls from considerable depths suggests that the normal habitat lies considerably below the surface.

LEPTOMEDUSAE.

Thaumantadidae.

Polyorchis.

Polyorchis penicillata Eschscholtz.

Melicertum penicillatum, Eschscholtz, 1829, p. 106, Pl. 8, Fig. 4.

Polyorchis penicillata, A. Agassiz, 1862, p. 349.

To the synonymy given by Mayer, 1910, p. 218, add

P. penicillata, Foerster, 1923, p. 32; and

P. minuta, Murbach & Shearer, 1902, p. 72; 1903; p. 174, Pl. 19, Fig. 3, Pl. 22, Fig. 1.

Material: Inez Bay, 1 specimen about 10-12 mm. in diameter.

In this specimen, less than half grown to judge from the size to which the species attains in Californian waters (Mayer, 1910, p. 218; Foerster, 1923, Table, p. 34) there are 31 well developed tentacles, as well as three (or perhaps four) rudimentary tentacular knobs; or a number nearly as great as given by Mayer for the adult. However, Foerster (1923, p. 32) records an average of 64 tentacles (or 16 per quadrant) for large specimens, suggesting that the *Zaca* example was about half grown as regards number of tentacles as well as in size.

According to Fewkes (1889) and to Foerster (1923) the edges of the radial canals already bear small projections even as early as the 16-tentacle stage, foreshadowing the lateral diverticula characteristic of the adult *Polyorchis*. And the latter author (1923, p. 34) records their number as "fairly constant, i.e., 30-40, for small as well as for large specimens." In the *Zaca* example the edges of the canals are at most slightly wavy, at a stage in growth at which Californian specimens show well developed diverticula. Since, however, this is the only feature differentiating this specimen

from its confreres in more northern waters, it does not seem sufficient to warrant even a distinct racial name.

Previous records for *Polyorchis penicillata* were wide-spread between northern Vancouver Island and Santa Barbara, California. The *Zaca* capture is interesting chiefly for extending the known range of the species southward to the Gulf of California.

LAODICEIDAE.

Chromatonema.

I have recently (1938, p. 109) given reasons for retaining this genus among the Leptomedusae as a member of the Laodiceidae, rather than classing it among the Anthomedusae as Ranson (1936) has done. The reader is also referred to Kramp (1919, p. 14) for discussion of the differences in gonad structure between *Chromatonema*, in which the gonads are broken up into a series of discontinuous masses, and in *Ptychogena*, where the gonad developed along either side of the pinnate radial canal is continuous. Named forms referable to *Chromatonema* as defined by Kramp (1919) are *rubrum* Fewkes, from the north Atlantic, *erythrogonon* Bigelow from the eastern tropical Pacific, and *hertwigi* Vanhöffen from the Indian Ocean. These are so closely allied that they may finally prove to be races or local varieties of one wide ranging species, but the recorded differences seem sufficient for the retention of all three names, at least for the time being.

***Chromatonema erythrogonon* Bigelow.**

Text-fig. 13.

Ptychogena erythrogonon, Bigelow, 1909, p. 150, Pl. 5, Fig. 1; Pl. 38, Figs. 8, 9; Pl. 39, Figs. 1-7; Vanhöffen, 1911, p. 220.

Chromatonema erythrogonon, Kramp, 1919, p. 11; 1933, p. 553.

Chromatonema rubrum (Partim), Ranson, 1936, p. 102.

Chromatonema rubrum var. *erythrogonon*, Ranson, 1936, p. 105.

Material: Stas. 139, 148, 219, 228, 244, in hauls from 910 and 914-0 meters, a total of 14 specimens ranging in diameter from about 15-16 to about 44 mm., all of them in more or less fragmentary condition.

The *Zaca* series corroborates Kramp's (1919, 1920) conclusion, based on the original account of *erythrogonon* (Bigelow, 1909), that the latter agrees in all important anatomical features (as it does in general appearance, including color) with the Atlantic *C. rubrum*. Microscopic examination of the marginal organs in the *Zaca* specimens, and reexamination of the original material of *erythrogonon*, also shows that absence of nematocysts in the cordyli of *erythrogonon*—mentioned by Kramp (1919, 1920) as a possible distinction—is only apparent, i.e., that my earlier illustration (1909, Pl. 38, Fig. 8) was faulty in this respect. Actually (Text-fig. 13), the tips of the cordyli are crowded with minute, fusiform nematocysts in the Pacific form, just as in the Atlantic. And Kramp was no doubt correct in considering what I named "cirri" (1909, Pl. 38, Fig. 9) for *erythrogonon* as identical with the cylindrical cordyli in *rubrum*; especially since one *Zaca* specimen bears two cordyli intermediate between the two extremes; whereas in none of them have I been able to detect anything that could be described as a "cirrus."

It appears, however, that on the average the Pacific form develops a somewhat larger number of tentacles than does the Atlantic. True, the discontinuity—if such exists—is not wide, for the largest (44 mm.) of the *Zaca* specimens and two others of 35-40 mm. have each 38-39 tentacles,

contrasting with a maximum of 20-24 in *C. rubrum* (maximum 7-8 per quadrant, Kramp, 1933, p. 552). But occasional specimens from the Pacific have considerably larger numbers, witness one *Zaca* specimen in which 57 can still be counted, also the presence of as many as 16 in a single quadrant of one of the original *Albatross* specimens, suggesting a maximum of perhaps 60-64, or a number 2-3 times as large as has yet been recorded for any specimen from the Atlantic. The variability in different sectors of the margin is further illustrated by one of the *Zaca* series (40 mm., Sta. 239) in which there are 6, 8, 13, and 11 or 12 in successive quadrants. The number of cordyli is also greater in *erythrogonon* than in *rubrum*, i.e., not far from 60 in specimens so far studied. However, there is no discontinuity in this respect between the two forms, the recorded maximum being up to 40-45 in *rubrum*, in which there are more often 2 than 1 between every tentacle, and sometimes no greater than this in *erythrogonon* in which there is more often 1 than 2 in each intertentacular gap. In the largest of the *Zaca* specimens, for example, with 38 or 39 tentacles, there is one cordylus, each, in 19 of the gaps, and 2 each in 14 of the gaps, i.e., a total of approximately 40. In another specimen the numbers in successive gaps were 1, 1, 1, 1, 2. However, three were observed in one gap.



Text-fig. 13.

Chromatonema erythrogonon
Bigelow, surface view of tip of
cordylus to show nematocysts,
from a preparation stained in
Delafield's haematoxylin, camera
drawing, about $\times 350$.

On the other hand, it appears that the number of sexual masses may average slightly smaller in *erythrogonon* than in *rubrum* (again, however, there is no discontinuity!), for in the latter this varies from 10-16 on either side of each radial canal (Kramp, 1933, p. 552), whereas among the *erythrogonon* so far seen, that were in good enough condition for the number to be determined, the maximum was 11, and most frequently 9 or 10. A minor difference that the future may or may not prove characteristic is that in *rubrum*, so far as known, the free-hanging portion of the manubrium is quadrate, but barrel-shaped in *erythrogonon*. It also appears that at maturity, *erythrogonon* tends to attain a larger size (up to 44 mm.) than does its Atlantic relative (recorded maximum, 27 mm.).

Vanhöffen's (1911) *hertwigi* from the Indian Ocean—if the single specimen was representative—appears to be characterized by a much larger number of cordyli⁵ (5) between every two tentacles than has ever been recorded, either for *rubrum* or *erythrogonon*. It agrees with the former, however, in the fact that the mouth was distinctly quadrate, and also in the number (20) of tentacles although it was much larger in size, i.e., 50 mm. in diameter.

The *Zaca* specimens are not in good enough condition to add anything important (other than as above) to the earlier account of *erythrogonon*. They do, however, provide interesting evidence of the constancy of coloration in this species, the tentacular bulbs, manubrium, and distal parts of the radial canals of the one specimen that is in good enough condition to show these being of the same brick-red (pale along the lines of attachment to the subumbrella and with pale cross at the base of the manubrium) and

⁵Vanhöffen names them "cirri," but his illustration (1911, p. 220, Fig. 13b) shows that actually they correspond to the cordyli of other members of *Chromatonema*.

the sexual blocks of the same salmon-pink as in the original series. In fact, all known representatives of *Chromatonema* agree in this respect.

The geographic range of *C. erythrogonon* appears to be decidedly circumscribed, for it has so far been taken only off the coasts of South and Central America between Latitude about 13° South (*Albatross* Sta. 4675) and the Gulf of California (*Zaca* Stas. 139, 148). And being so large, and so conspicuous in color, it is not likely that it would have been overlooked in the collections that have been made around Japan, around the Hawaiian Islands, and in Philippine waters, did it occur there as frequently as it evidently does in the eastern side of the Pacific at comparable latitudes. In this respect it appears to differ from its Atlantic confrere, the distribution of which is general from the continental slope of America to northern Europe as well as seemingly more northerly, for its known range extends up to Davis Strait and the vicinity of Iceland (Kramp, 1919, Chart I, p. 13; 1920, p. 8), whereas it is not known farther south than the vicinity of Bermuda (Bigelow, 1938).

Aequoridae.

Zygocanna.

Zygocanna vagans Bigelow.

Text-fig. 14.

Zygocanna vagans, Bigelow, 1912, p. 255; 1919, p. 315, Pl. 42, Figs. 5-7; Pl. 43, Fig. 6.

Material: Sta. 225, 910-0 meters, 2 specimens, 40 and 33 mm. in diameter. Sta. 233, 910-0 meters, 2 specimens, 33 and 34 mm. in diameter.

These specimens all agree so closely with the type series of *Z. vagans* (Bigelow, 1912; 1919) that there is no doubt of their identity though the locality of capture is in the opposite side of the Pacific. They add, however, to our knowledge of the species by showing that the early branchings of the canals as indicated by the figures formed by the courses of the canal stripes on the aboral wall of the manubrium, not only are decidedly irregular (Text-fig. 14), but that the outermost branching of the canals is not as closely associated with the margin of the manubrium as it was in the original series, but may occasionally take place considerably centrifugal to the latter. Such for example is the case in one of the specimens from Sta. 233 (Text-fig. 14A). Furthermore, the sinus-like expansions of the gastric cavity along the lines of the groups of successively formed canals (Bigelow, 1919, p. 316), especially well developed in this specimen, show that no sharp line of demarcation can be drawn between manubrium and canal, in this highly variable species.

Associated, as I have pointed out, with this type of branching, the canals are in groups; the number of groups "varies according to the number of branchings which each main stem has undergone, and the number of canals varies from group to group" (Bigelow, 1919, p. 316). In the two members of the original series in which the four primary trunks could be identified, the number of canals from each that reached the ring canal varied between 5 and 12. In the present series again, in two specimens in which these primary trunks are identifiable, the number of canals to which each of the latter gives rise ranges between 4 and 7.

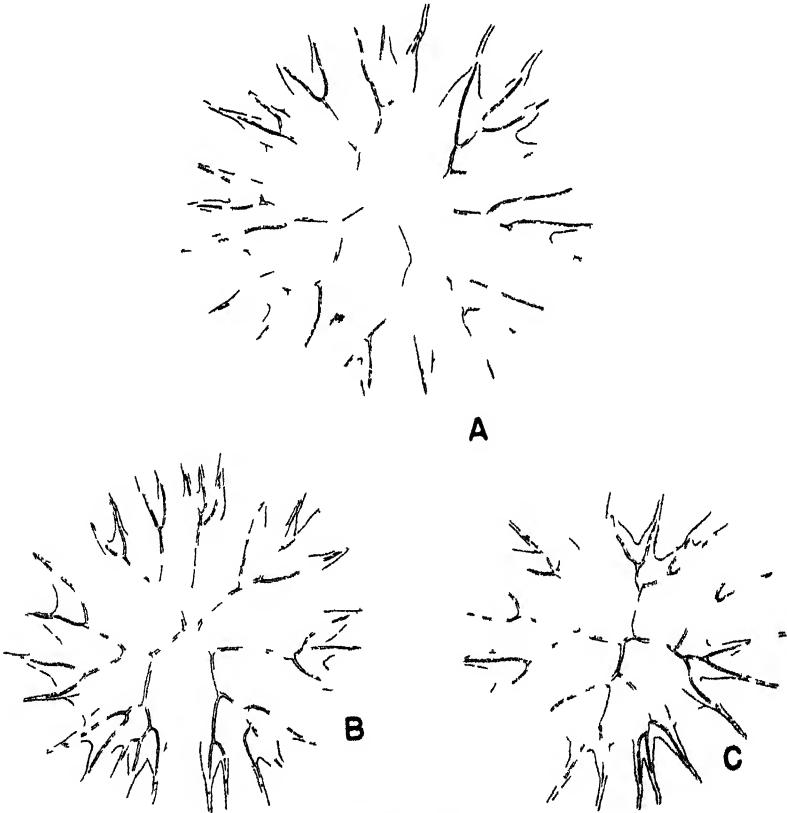
The smallest number of groups in which the canals are associated at the zone where they depart from the manubrium is 7 in the present series; the largest number is 10. The number of canals in a given group may be as small as 1 or as great as 8 even in different sectors of a given individual, the latter being the largest number yet observed.

The Philippine and *Zaca* series combined show that the numbers of canals and of tentacles tend to increase (though irregularly) with the growth of the medusa, as follows:

DIAMETER	CANALS	TENTACLES	RATIO TENTACLES TO CANALS
*29 mm.	33	42	1.3
31 mm.	27	32	1.2
32 mm.	22	33	1.5
34 mm.	26	30	1.2
*36 mm.	29	28	1.0
38 mm.	30	30	1.0
*39 mm.	38	54	1.4
*40 mm.	35	42	1.2
*43 mm.	46	46	1.0
*50 mm.	31	45	1.5
*68 mm.	45	50	1.1
*76 mm.	38	70	1.8

* Philippine specimens

As the larger of the Philippine specimens had well-developed gonads, it is probable that the final number of canals is not likely to be much more than 45 in any specimen—perhaps not less than 35.



Text-fig. 14.

Zygocanna vagans Bigelow, central portions of discs of specimens from Stas. 225 (A) and 233 (B, C) to show canal stripes, camera drawings, about $\times 3$.

In two, only, of the specimens so far examined, was the number of tentacles less than that of the canals; greater by at least 1 in all others. But comparison between size, number of canals and number of tentacles (ratios —, Table, p. 300) fails to suggest any general tendency for the disparity in number between the two classes of organs either to increase or to decrease with the growth of the medusa.

In the one member of the original (Philippine) series, on which a complete count of the marginal organs was made, there were from 4 to 11 rudimentary tentacular knobs between every two large tentacles. The fact that among the *Zaca* specimens the number was in one instance as small as 1 but frequently as large as 7, further emphasizes the wide variations in this respect that are to be expected in different sectors of the margin, in individual specimens.

The large size of the excretory papillae has already been commented upon in the original accounts of the species (Bigelow, 1912; 1919, Pl. 42, Fig. 6), which the *Zaca* series confirms.

In all of the present series, the gonads (immature) are confined to the outer $\frac{1}{4}$ or so of the radial canals. The condition, however, of the type specimen of 39 mm. (Bigelow, 1919, Pl. 43, Fig. 61) shows that they may already occupy more than $\frac{1}{2}$ the lengths of the canals in medusae no larger—another evidence of variability of the species.

The subumbral gelatinous papillae, characteristic of the species, occupy the same locations in the *Zaca* series as in the original specimens, being confined to a row between every two adjacent canals and to the roof of the manubrium. The intercanalar rows consist in some cases of entirely separate conical prominences, in others of a sharp crest bearing such; the number along each series varies from 1-9, as against 5-10, with a maximum of 15 in the Philippine series. As in the latter the papillae are confined to the inner $\frac{2}{3}$ or $\frac{3}{4}$ of the bell diameter. The chief difference in sculpture between the *Zaca* and Philippine specimens is that the latter had up to 16 rounded knobs within the limits of the manubrium, whereas the largest number of such knobs among the *Zaca* series was only three. But in view of variability in other characters this difference does not seem specifically significant.

The most interesting aspect of the present captures is evidence of the wide-ranging nature of *Z. vagans*. The facts not only that *vagans* has now been found in both sides of the Pacific, but that all representatives of *Zygocanna* recently taken are referable to it, raises the question whether the regular bifurcation of canals well distal to the margin of the manubrium described and figured by Haeckel (1879) for his *Zygocanna costata* from New Guinea correctly represented the normal state, or whether it actually represents Haeckel's idealization of the alcoholic specimen on which he based the species (and genus). Even in the latter case, however, there remains to separate *vagans* from *costata* the presence of the subumbral papillae in the former, contrasted with their absence (or at least with Haeckel's failure to mention them) in the latter; and of radial exumbral ridges in *costata* of which there is no trace in *vagans*. The *Zaca* series does not help toward a final decision as to whether Mayer (1910) was correct in uniting *costata* with Péron & Lesueur's (1809) old species *pleuronota*. However, the fact that the members of two successive series of *vagans* (taken so far apart in time and in space) lack any trace of peduncle, argues against Mayer's (1910, p. 339) suggestion that Haeckel's *Zygocannula* (with well-developed peduncle) is an advanced stage of *Zygocanna*.

TRACHOMEDUSAE.

Geryonidae.

Liriope.***Liriope tetraphylla* Chamisso & Eysenhardt.**

Geryonia tetraphylla, Chamisso & Eysenhardt, 1821, p. 357, Pl. 27, Fig. 2.

For recent discussions of this (apparently) monotypic genus, see Browne (1924); Thiel (1936); and Bigelow (1938).

Material: Sta. 227, 210-0 meters, one specimen about 12 mm. in diameter.

In this specimen the gonads are triangular, with their bases occupying most of the periphery of the bell, but not yet actually in contact, i.e., it is intermediate between the so-called "*rosacea*" and "*compacta*" stages already pictured from the Eastern Tropical Pacific (Bigelow, 1909, Pl. 3, Figs. 7, 8). *Liriope* with gonads of this type has so frequently been reported—especially from the high seas—that the present example adds nothing significant to our previous knowledge of this much-vexed genus.

Trachynemidae.

Colobonema.***Colobonema typicum* Maas.**

Homoeonema typicum, Maas, 1897, p. 22, Pl. 3, Figs. 1-3.

For recent discussion of the synonymy of this species, see Bigelow, 1938, p. 116.

Material: Sta. 219, 540-0 meters, 1 specimen, about 25 mm. high.

This specimen—in good enough condition for positive identification—adds nothing to previous knowledge of the morphology of this well-known bathypelagic medusa. Having been taken widespread in the Eastern Tropical Pacific, including the offing of Costa Rica and Gulf of California (Maas, 1907; Bigelow, 1909), it is somewhat astonishing that the *Zaca* collection yielded only a single example of it.

Halicreidae.

Halicreas.***Halicreas minimum* Fewkes.**

Halicreas minimum, Fewkes, 1882, p. 306.

Halicreas papillosum, Vanhöffen, 1902a, p. 68, Pl. 9, Figs. 7-8; Pl. 11, Fig. 30.

For reasons for the final relegation of *papillosum* to the synonymy of *minimum*, and for lists of the more important references, see Bigelow, 1938, pp. 121, 122.

Material: Stas. 165, 210, 225, 227, 228, 230, 234, 15 specimens, all in hauls from 910-0 meters.

The condition of the specimens is so poor that they add nothing to previous accounts of this well-known species. All, however, show the characteristic exumbrel papillae, and it is chiefly on these that their identification rests.

Having already been recorded at many stations in the eastern side of

the Tropical Pacific (Bigelow, 1909), *H. minimum* was to be expected in the region explored by the *Zaca*. It is, in fact, now known to be one of the most generally distributed and frequently occurring of bathypelagic medusae in the open oceans, in low and mid-latitudes, as discussed elsewhere (Thiel, 1936, p. 72; Bigelow, 1938, p. 122).

NARCOMEDUSAE.

Solmaridae.

The majority of recent authors have concurred in uniting in this one family all Narcomedusae that lack gastric pockets. Ranson (1936), on the other hand, has revived the old family designation Peganthidae, for such of them as have the gonads localized in interradian diverticulae of the gastric wall, as opposed to those in which they extend, ring-like, right around the margin of the stomach. To use the conformation of the gonads as a basis for family separation among the Narcomedusae that lack gastric pockets would, however, run counter to another set of alternative characters, namely, the presence or absence (at least in one generation) of a canal system and of otoporphae. Our knowledge of the existence of solmarids with canals and otoporphae, but with a simple annular gonad, rests not only on Haeckel's (1879; 1881) account and figures (from life) of his *Polycolpa forskalii* from the Red Sea, but equally on Browne's (1916) discovery of a second unnamed Narcomedusa of this type from the Indian Ocean. In fact, the *Cunina prolifera* of Gegenbaur (for synonymy, see Mayer, 1910, p. 480), which also has an annular gonad and otoporphae, appears also to belong to this group, for none of the published illustrations of this species show any gastric pockets. Stschelkanowzew (1906, p. 483) indeed states definitely that it has none, but that its stomach, is perfectly round in life, though taking an angular outline when preserved as is shown by Mayer (1910, p. 471, Fig. 319A). *C. prolifera* should then be removed from the Aeginidae to the Solmaridae (and referred to *Polycolpa* if that genus be recognized, see below) as Stschelkanowzew suggested, though he did not actually go so far as to make this alteration.

The question is further complicated by the fact that the canals and otoporphae, so conspicuous in the primary generation of *Pegantha* are lacking in the second parasitic generation that develops within that genus, at least up to the most advanced stage to which development has been followed (Bigelow, 1909, p. 93), so that morphological diagnosis that applies to one generation would not to the other. It therefore seems wiser to maintain the family Solmaridae as widely inclusive for the time being; admitting, however, that this may be only a temporary stand, in the slow and spasmodic growth of our knowledge of the Narcomedusae.

Within the Solmaridae, as thus conceived, three groups of species appear to be rather definitely definable: A, with simple annular gonad, lacking canals and otoporphae; B, with simple annular gonad, with canals, and with otoporphae; and C, with interradian sexual sacs (whether or not combined with an annular gonad), with canals, and with otoporphae. The first of these groupings is now generally referred to *Solmaris*; the second is the genus *Polycolpa* of Haeckel (made by Mayer, 1910, a synonym of *Solmaris*); it is with the third that we are concerned here.

For the members of this last group, Haeckel (1879) revived the old genera *Pegasia* of Péron & Lesueur (1809) and *Polyxenia* of Eschscholtz (1829), as well as proposing his new genus *Pegantha*. And it is certain that in any final revision these two old generic names must be taken into account, for we have as good grounds for identifying them with the medusae in question, as in most of the cases in which final disposition of the early medusan names has been made.

Actually, it seems that the earliest description of a typical peganthid was neither of *Pegasia* nor of *Polyxenia*, but of the *Medusa mollicina* of Forskål (1775). This Péron & Lesueur (1809) later referred to their genus *Faveola*, but incorrectly since the first mentioned member (hence type species) of the latter—the *Medusa pilearis* of Linnaeus (1766)—was an Anthomedusa and probably what is now known as *Leuckartiara*. The next description of what was probably a peganthid (though no indication was given as to presence or absence of a canal system nor of otoporpa) was by Eschscholtz (1829) as *Polyxenia cyanostylis*. Meantime, however, Péron & Lesueur (1809) had published a brief notice of *Pegasia dodecagona*. And while their account and the subsequent illustration by Blainville (1834) are unrecognizable if taken *per se*, Haeckel (1879, p. 331) from personal examination of one of Péron & Lesueur's original specimens, placed it in his family Peganthidae—thereby at least implying a lack of gastric pockets, but presence of a peripheral canal system—described its gonads and even counted the otcysts. Our choice lies, then, between ignoring Haeckel's diagnosis as Vanhöffen (1908) has done (partly on the ground that it was not accompanied by an illustration) or accepting *Pegasia* as the oldest generic name applicable to the group in question. And the latter alternative appears much the more likely to conduce toward stability of nomenclature. In other words, we can credit Haeckel with doing for *Pegasia* what Chun (1897) did for *Abylopsis tetragona* Otto, among siphonophores, i.e., with establishing the status of an old species from reexamination of a type specimen, the original account of which had been wholly inadequate, or even erroneous.

Accepting the validity of the name *Pegasia*, we have still to decide whether all known members of the group to which it belongs (i.e., solmarids with otoporpa, with canals, and with genital diverticulae) should be referred to it, or whether they represent more than one genus. Generic grouping based on the number of tentacles, suggested by Vanhöffen (1908; 1911; 1912) having been proven untenable in this case, decision rests on what value in classification is to be assigned to the conformation of the gonads. And while Vanhöffen (1908), Mayer (1910), and subsequent authors generally have been of the opinion that this is not of more than specific import in the group in question, it seems wiser to reserve judgment, until the time (if ever), when some student has the opportunity to examine actual specimens in which an annular gonad is combined with interrational sexual sacs—i.e., referable either to *Polyxenia*, or to *Pegasia* as redefined by Haeckel.

Accordingly, the generic name *Pegantha* is retained here (as earlier by me) with the Haeckelian diagnosis, i.e., for Solmaridae in which the sexual products are confined to interrational outpocketings from the gastric margin, irrespective of the number of tentacles. Should it prove, in the future, that the gonads must be discarded here, as a generic character, the name *Pegasia* (or if not *Pegasia*, then *Polyxenia*) will have priority.

Pegantha.

Anatomically, *Pegantha* is one of the best known of narcomedusan genera. Our knowledge, however, of specific relationships within the genus has not significantly advanced since 1918, when I briefly outlined the existing status in this respect (Bigelow, 1918, p. 395). Nor does the present series contribute toward a final solution, for one of the two specimens of *Pegantha* that it contains, belongs to a species that has already been fully described, while the other is not in good enough condition for positive identification.

***Pegantha clara* R. P. Bigelow.**

Text-figs. 15, 16.

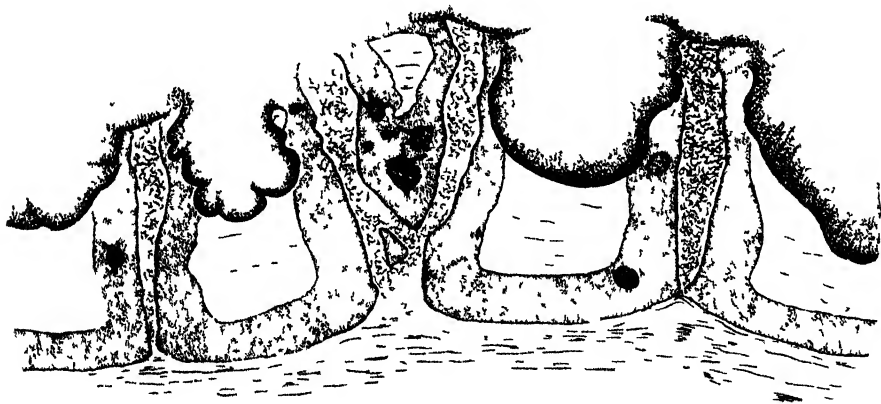
Pegantha clara, R. P. Bigelow, 1909, p. 80.

Pegantha smaragdina, H. B. Bigelow, 1909, p. 90, Pl. 14, Figs. 1, 2; Pl. 19, Figs. 1-9, Pls. 22-26.

To the synonymy and list of references given earlier by me (Bigelow, 1938, p. 134), add *P. smaragdina*, Hanitzsch, 1911, p. 225.

Material: Sta. 230, 910-0 meters, 1 specimen about 55 mm. in diameter with 25 tentacles, in fair condition.

In its low disc without exumbral sculpture, and simple gonads (hemispherical when relaxed but more or less constricted when contracted), the *Zaca* specimen agrees very well with the earlier accounts by R. P. Bigelow of the Atlantic *P. clara* and by me almost simultaneously of *P. smaragdina* from the Eastern Tropical Pacific. The number of tentacles (25, 2 much smaller than the others) also falls well within the recorded limits (19-34). And this also applies to the number of otocysts, of which there are five (4 of them with well developed otoporpa, but 1 lacking such an organ) in the only sector in which they can be counted, and three, with otoporpa, close together in the next, so localized as to suggest a total of 6-8. In short, it corroborates the conclusion arrived at first by Vanhoffen (1912a) and subsequently by me (1938) that *smaragdina* cannot be distinguished specifically from *clara*. In my original (1909) discussion of the former it was suggested

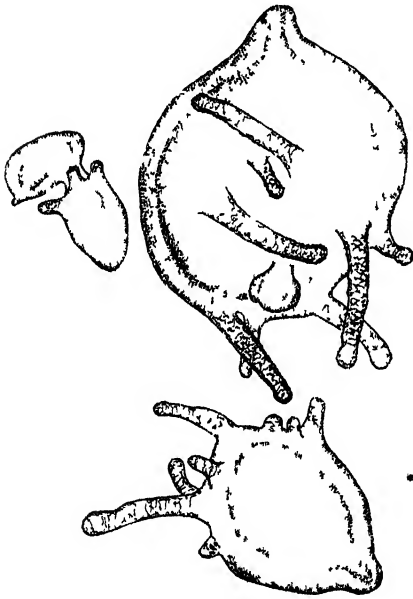


Text-fig. 15.

Pegantha clara R. P. Bigelow, aboral view of gonads and canal system with polyp larvae, camera drawing, about $\times 7$.

that the ova (difficult of detection because of their small size) may develop irregularly over the wall of the manubrium, as is the case according to Stschelkanowzew (1906) in *Cunina proboscidea*, i.e., that it may be the males alone that develop discrete gonads. In fact, ova have not been definitely identified as yet, in any *Pegantha*, so far as I am aware. And surface views of the sexual sacs of the *Zaca* specimen are at least compatible with this suggestion, no ova being visible, even after staining, but only very closely crowded masses of minute cells, suggesting stages in spermatogenesis.

Anatomically, the specimen is interesting as showing individual tendency toward abnormality, for the otopercpae vary greatly in length, while one of the peronii is abnormally broad distally, and bifid proximally, with a small tentacle associated with the one branch but none with the other, the two branches being separated by a canal, but one so much shorter than the others that it fails to reach the margin of the bell (Text-fig. 15).



Text-fig. 16.

Pegantha clara R. P. Bigelow, enlarged view of three of the larvae shown in Fig. 15, camera drawing, $\times 42$.

The most interesting feature of the *Zaca* specimen is that its canal system contains several polyp-larvae (Text-fig. 16) with much younger (cleavage) stages in the mesoglea, agreeing very closely with those described by me (1909) for one of the two *Albatross* specimens from the Eastern Pacific. These have not been found in any Atlantic example of the species that has yet been examined. It is worth repeating, however, in this connection, that small medusae, resembling the 2nd generation of *P. clara*, have often been observed in the gastrovascular cavity of the Mediterranean *Narcomedusa* usually referred to in literature as *Cunina prolifera* Gegenbaur, but which is not a *Cunina* but a peganthid (p. 303). Unfortunately, the histological condition of the *Zaca* specimen was not good enough to add anything of moment to my earlier account of the developmental stages. Their presence, however, in this second example shows that it is characteristic of the earliest stages to be confined to the mesoglea of the exumbrella of the parent, overlying—in this case—the part of the vascular system that is

occupied by the older larvae. It is also interesting that the latter, like those earlier described, show stages in budding at the aboral side.

Were it alone in *P. clara* that this type of development had been observed, it might reasonably be questioned whether the resultant small medusae do indeed belong to the developmental cycle of the large medusae within which they occur, for we lack actual factual knowledge of the source of the infesting larvae. Since, however, Stschelkanowzew (1906) was able to show that similar larvae, found parasitic within *Cunina proboscidea*, develop from the fertilized ova of that same species, we may assume that the same is true of *Pegantha*.

In the case of *Cunina*, it appears, indeed, (from Stschelkanowzew's studies), that the larvae are the offspring of the same individuals within which they develop. Since, however, the larvae have now been found in a specimen of *P. clara* lacking any trace of gonads, and in a second in which the latter are well developed, it seems that in this species any large individual (whether or not mature) may become infested if in the vicinity of others that are actually setting free their eggs and sperm in the water. And this seems the more likely, from the fact that in this particular Narcomedusa (in contrast to *Cunina proboscidea*) the earliest developmental stages are to be found in the exumbrel mesoglea. In other words, there is no necessity for assuming that the larvae found within a given individual are its own offspring. But this whole matter necessarily remains open, until the fertilization of the egg and its actual penetration have been traced.

According to Hanitzsch⁷ (1911) interpretation, based on Stschelkanowzew's (1906) cytological studies of the oogenesis of *Cunina*, the mitotically dividing amoeboid cells of *P. clara* (Bigelow, 1909, Pl. 22, Figs. 8, 9) represent the product either of the last maturation or of the first cleavage division, and those amitotically dividing (which later act as the nurse cells for the embryo) are oocytes that have lost their character as sex cells.

A serious gap still remains in our knowledge of the developmental cycle of *P. clara*, between the medusae of generation II (i.e., the small parasitic) which are set free at what may be termed the "*Solmissus*" stage when some 3 mm. in diameter, and those of generation I, within which they have been found. In the case of *Cunina proboscidea* Stschelkanowzew (1906) concluded that an asexual polyp generation intervenes, both because the direct development of the medusae of generation II into those of generation I seems precluded by differences in structure, and because he believed he could identify as the young of *C. proboscidea* (by the shape of the otoporpa) the medusae set free from one of the two species of narcomedusan stolons that are often found parasitic within the gastric cavity of *Geryonia*.⁶ Metschnikoff (1874, p. 34) had in fact made this same suggestion, long before. These stolons, as is well known, are the growth products of ciliated larvae, which Woltereck (1905, Figs. 12-14) traced back to early cleavage stages in the mesogloea of *Geryonia*. But the actual process by which the latter is parasitized by them has not yet been observed; we have only Stschelkanowzew's suggestion, accepted by Hanitzsch (1921, p. 225), that the small medusae of *C. proboscidea* of generation II are eaten by the *Geryonia* and that their eggs and sperm come together within the cavities of the latter.⁷

Perhaps a stolon-generation intervenes, in *Pegantha clara* also, between the medusae of generations I and II. But it is equally possible that in this species the large medusae of generation I develop directly from the fertilized eggs of the small "solmarid" medusae of generation II.

⁶ These are the stolons usually referred to as "*Cunina parasitica* Metschnikoff."

⁷ The development of *Cunina proboscidea* has been discussed not only by Metschnikoff (1886) and Stschelkanowzew (1906), but subsequently in great detail by Hanitzsch (1911-1921).

? *Pegantha martagon* Haeckel.

Pegantha martagon, Haeckel, 1879, p. 332; Bigelow, 1909, p. 83, Pl. 18, Figs. 1-8; Mayer, 1910, p. 443.

Pegantha simplex, Bigelow, 1904, p. 260, Pl. 5, Figs. 19, 20.

Material: Sta. 234, 1 fragmentary specimen, about 18 mm. in diameter, with 12 tentacles.

The condition of this specimen is not good enough for positive identification, further than that absence of gastric pouches and presence of a well-developed canal system prove it a *Pegantha*. It is tentatively referred to *P. martagon* for the following reasons: 1, the bell is high-rounded, but above the level of the tentacular insertions, shows no trace of the exumbra sculpture that is so prominent in *P. triloba*; 2, the gonads, while showing a certain amount of irregular wrinkling and lobing are not definitely subdivided. The margin is so much damaged as to prevent counting the otocysts; it is unfortunate, in particular that the otoporae have been entirely destroyed, because the structure of these is one of the respects in which *P. martagon* differs the most sharply from *P. triloba* (Bigelow, 1909).

Solmissus.

Ranson (1936, p. 206) in his recent discussion of *Solmissus*, is of the opinion that *S. incisa* Fewkes is a "forme géante" of *S. albescens* Gegenbaur, but that the Indo-Pacific *S. marshalli* Agassiz & Mayer is a well defined species rather than a variety of *albescens* as I (1909; 1919) formerly suggested.

Solmissus marshalli Agassiz & Mayer.

Solmissus marshalli, Agassiz & Mayer, 1902, p. 151, Pl. 5, Figs. 23-25; Bigelow, 1909, p. 64, Pl. 16, Figs. 5-6, Pl. 21, Figs. 4, 6-8; 1919, p. 329; 1938, p. 129; Mayer, 1910, p. 484; Thiel, 1936, p. 68; Ranson, 1936, p. 208.

Solmissus punctatus, Mayer, 1906, p. 1133.

Solmissus flavescens, Vanhöffen, 1908, p. 56, Pl. 2, Figs. 9-10, Pl. 3, Figs. 20-22.

(*Non Solmissus flavescens* Kolliker).

Material: Sta. 233, 2 specimens respectively about 34 mm. and 52 mm. in diameter.

Tentative identification of these two specimens rests on the fact that, in each case, traces of the outlines of gastric pockets in the radii of the tentacular roots are still to be seen, combined with a flat-lenticular type of bell characteristic of *Solmissus* of the *albescens-marshalli* group. Failing any trace of the otocysts, and lacking knowledge of the precise contour of the gastric pockets, they are referred to *marshalli* on geographical grounds, because *albescens*—the common *Solmissus* of the Mediterranean—has not yet been taken in the Pacific.

Unfortunately, the condition of the specimens is so poor that the number of tentacles cannot be stated exactly, further than that in one case 8 large tentacular roots were detected and in the other nine. But these numbers are so much smaller than is usual in full-grown *marshalli* (usually 12-16) as to suggest that there had been more tentacles in life, but that some had been obliterated.

It has long been known that *marshalli* (or the *marshalli* variant of *albescens*) is widespread in the tropical and subtropical belts of the Pacific, Indian and Atlantic oceans, while Ranson (1936) has recently reported it from the Mediterranean.

*Aeginidae.**Aeginura.*

Recent authors agree that all representatives of *Aeginura* that have come to hand, subsequent to Haeckel's (1879) original account of the genus, are referable to the single species *grimaldii* Maas (1904)—of which *weberi* Maas (1905) and *grimaldii* var. *mundi*, *guinensis* and *obscura* of Vanhöffen (1908) are synonyms. The relationship, however, of *grimaldii* to the medusa (*myosura*) on which Haeckel founded the genus, and to Haeckel's *Cunoctona nausithoe* and *C. lanzerotae* (which are described as having otoporpa) is still in doubt; may, in fact, always remain so. Having recently (1938, p. 132) discussed this question, there is no need for me to revive it here.

Recent students of Narcomedusae have been unanimously of the opinion that the chief generic character of *Aeginura* is the constant presence of 8 tentacles and 16 gastric pockets; and it has seemed at least probable that the presence of small secondary tentacles on the margin is equally diagnostic, for while Haeckel (1879; 1881) neither mentioned nor pictured any such for *myosura*, their apparent absence in the latter may well have been due to the mutilated state of the unique (alcoholic) specimen. But it is now necessary to redefine the genus, or to institute a new one, for the *Zaca* collection contains a specimen that agrees with *Aeginura* in the arrangement of the gastric pockets in relation to the large primary tentacles, and in the presence of small secondary tentacles on the bell-margin between the peronii, but in which the number of tentacles, and of primary gastric pockets is eleven, instead of eight. Decision in this case obviously depends on the relative phylogenetic weight to be attached to metameral number, as compared with the presence of the secondary tentacles. About this opinions may differ. Since, however, the number of primary tentacles in the Narcomedusae may either be strictly determinate, as for instance in *Solmundella* and *Cunocantha*, or highly variable as in some species of *Pegantha* and *Cunina*, whereas the presence of secondary tentacles is a feature peculiar (so far as yet known) to *Aeginura*, it seems to me wisest to use the latter as the primary generic character for that genus, expanding the latter to include species with more than 8 tentacles.

Aeginura beebei sp. nov.

(Text-figs. 17-20).

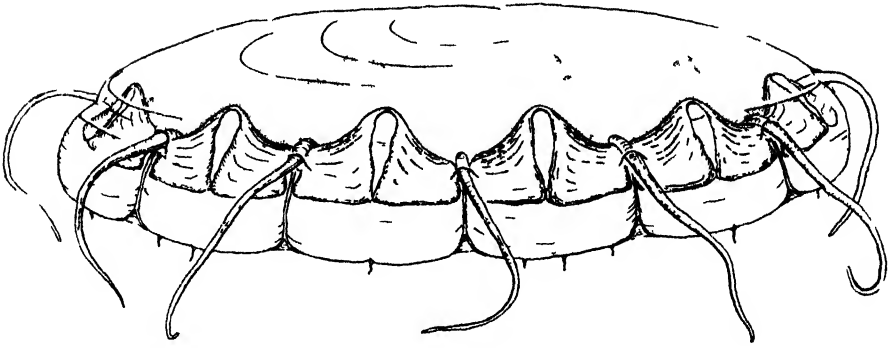
Material: Sta. 227, 910-0 meters, 1 specimen, about 100 mm. in diameter in fair condition.

This specimen (Text-figs. 17-20) is perhaps the most interesting find among the *Zaca* medusae, for while in general appearance it resembles *Solmisisus*, critical examination shows that it actually agrees, in all significant anatomical characters, with the bathypelagic medusa *Aeginura grimaldii*. It differs, however, from the latter in the fact that it has (as just stated) a larger number of antimeres (11) than has ever been recorded for *Ae. grimaldii* in which the normal 8 has never been exceeded—though Ranson (1936, p. 210) records one specimen with as few as five.

Most at least of the secondary tentacles are intact, and certainly a majority of the otocysts: the numbers of marginal organs counted per antimeres, being as follows:—

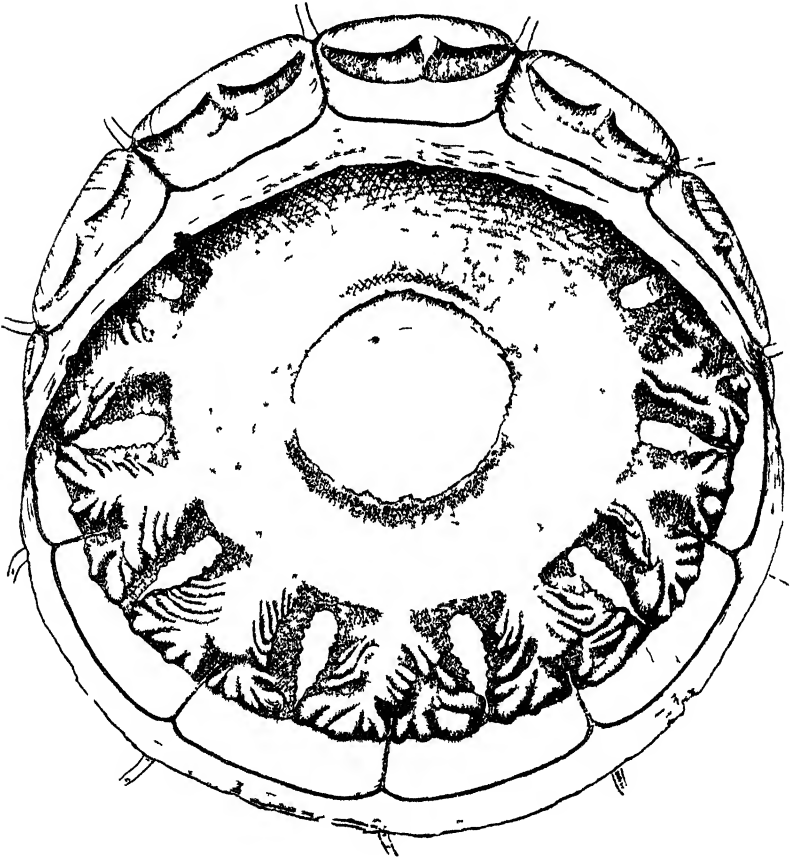
Tentacles	3	1	2	2	1	1	3	1	2	1	2
Otocysts	5	2	4	1	2	3	6	3	3	2	2

Thus, there is no evidence that the number of secondary tentacles ever exceeds 3 per sector, while in at least 5 of the sectors, the condition of the



Text-fig. 17.

Aeginura beebei, sp. nov., lateral-oblique view of type specimen, slightly more than natural size.



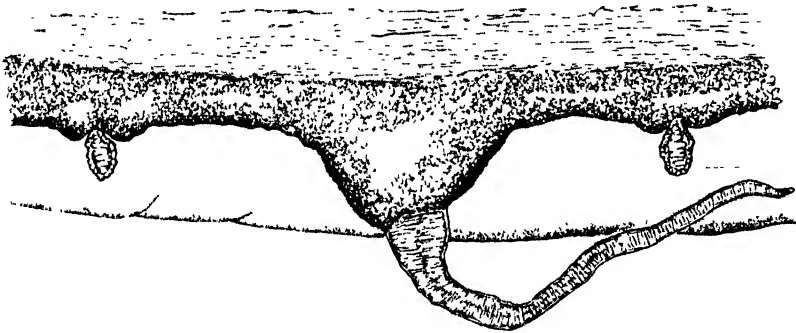
Text fig. 18.

Aeginura beebei, sp. nov., oral-oblique view of type specimen, slightly more than natural size.

margin was so good as to allow positive assertion that there was only one secondary tentacle. In *grimaldii* (or its synonyms), the recorded number per marginal sector ranges from 2 to 5, the total thus being about the same as in the new species.

Structurally, the secondary tentacles of *beebei* differ from the primary tentacles in the fact that they lack entodermal roots, while their bases are much swollen (Text-fig. 19), hence there is no reason to suppose that the former ever develop into the latter. In detail (i.e., in the core of chordate entodermal cells and in the slender filament) they agree very closely with Vanhöffen's (1908, Pl. 9, Fig. 28) illustration of the corresponding structures in his "*Cunoctana obscura*," which was undoubtedly identical with *Ae. grimaldii*.

A secondary tentacle is flanked, in so many cases, by an otocyst on either hand (Text-fig. 19) that this appears to be the basic state. However, the presence of three otocysts each, in two of the marginal sectors but of only one secondary tentacle, proves that neither the numerical relationship between the two, nor their relative locations on the margin, are determinate. A similar variation in number and spacing of otocysts has already been recorded for *grimaldii* (Vanhöffen, 1908). On the average, the number of otocysts per sector (there being fewer secondary tentacles) is somewhat smaller in the new species than in *grimaldii*, but the difference may not be great enough to be of diagnostic significance. In their structure (Text-fig. 20) the otocysts are of the usual aeginid type.

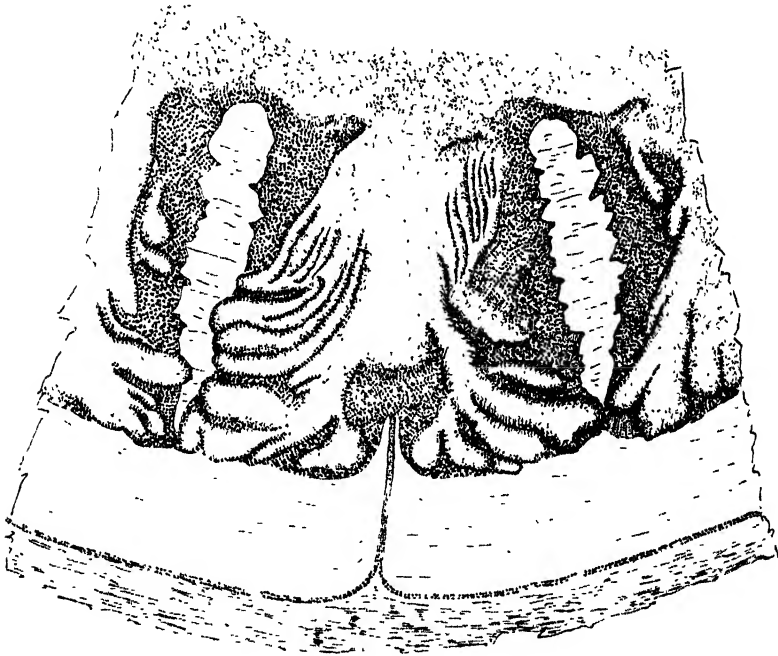


Text-fig. 19.

Aeginura beebei, sp. nov., aboral view of portion of margin, with secondary tentacle and otocyst, camera drawing, $\times 66$.

The specimen corroborates previous observations to the effect that in *Aeginura* the interradiar notches that indent the margin of the gastric cavity are much deeper than the perradiar, such for example was the case in the specimen from the East Indies figured by Maas (1905) as *Ae. webberi*; in the *Albatross* specimens from the Eastern Tropical Pacific and Northwestern Pacific (Bigelow, 1909, p. 80; 1913, p. 62), and likewise in Maas' (1904, Pl. 3, Fig. 20) original figure of *Ae. grimaldii*, in which the interradiar notches are pictured as about twice as deep as the perradiar. Haeckel (1879; 1881), on the other hand, pictures the reverse for *Ae. myosura*, this being one of the reasons for doubting whether this species has been seen subsequently. In the *Zaca* specimen of *Ae. beebei*, the interradiar notches are about 16-17 mm. deep, but the perradiar only 4-5 mm. The gastric pockets themselves are rhomboid in outline (Text-figs. 18, 20), broader distally than proximally, with the outer angles of adjacent pockets very close together. Surface views, in fact, suggest that they may even be confluent, which would be unique among Narcomedusae. But the condition

of the specimen is not good enough for positive determination of this point, though it was easy to trace the general outlines of the pockets by surface examination, verified by the injection of air. A specific character, which, while minor in itself, is again unique, so far as known among aeginids, is that the interradian margins of the pockets are jagged or lobate (Text-fig. 20). Neither surface view nor injection yielded any evidence of the presence of a peripheral canal system, in which *beebei* agrees with *grimaldii*. The central part of the stomach has been largely torn away—the remnants, however, suggest a simple circular mouth (Text-fig. 18).



Text-fig. 20.

Aeginura beebei, sp. nov., oral view of gastric pockets, about $\times 3$.

The gastric wall, at the interradian sides of the pockets, is thrown into a series of folds directed obliquely distal (Text-figs. 18, 20), no doubt the sites of the sexual products. Surface views suggest that the specimen is a male—at least no individual eggs are to be seen. And to judge from analogy with *Ae. grimaldii*, the latter might be expected to be so large as to be conspicuous.

A striking feature of the specimen is that the subumbrella is deeply indented with triangular depressions along the lines of the interradian septa that separate the gastric pockets, and also with furrows along the perradian septa. Thus, were the gastric wall to be stripped off, the subumbrellal zone occupied by the pockets would appear as alternate triangular prominences and depressions, the former with their bases directed distally, and shallowly notched in the perradii, the latter with their bases directed toward the center of the bell. The bell is low discoid in form, about $\frac{1}{4}$ as high (18 mm.) as broad, with very shallow bell cavity, i.e., hardly deeper than the breadth of the marginal groove. There is no exumbrellal sculpture, other than the shallow furrows along the lines of the peronii that are a common feature among Narcomedusae.

The gastric wall in the preserved state (formalin) is pale purplish. Otherwise the specimen is colorless.

The features in which *Ae. beebei* most sharply differ from *Ae. grimaldii* are 1, larger (and probably indeterminate) metameral number; 2, presence of prominent subumbbral sculpture; 3, much larger size at maturity; 4, entire lack of the distinctive bathypelagic pigmentation.

Obviously, the one capture, having been made in an open net, yields no information as to the normal bathymetric occurrence of the species, but the fact that it is so faintly pigmented suggests that it is a creature of the upper waters.

***Aeginura grimaldii* Maas.**

Aeginura grimaldii, Maas, 1904, p. 38, Pl. 3, Figs. 19-28.

See Bigelow, 1938, p. 132, for recent discussion of *Aeginura* with the reasons why it seems wiser to retain Maas' species *grimaldii* as distinct rather than to unite it with Haeckel's (1879) old species *myosura*, *nausithoe*, and *lanzerotae* as Thiel (1936) has done in his historical survey.

Material: Sta. 227, 910-0 meters, 1 fragmentary specimen about 23 mm. in diameter.

Sta. 228, 910-0 meters, fragments.

Aeginura grimaldii is represented so regularly in collections from deep water that it must be one of the most generally and frequently distributed of bathypelagic medusae. As a rule, however, the specimens taken have been badly damaged amid the mass of other plankton. And the present examples are no exception, for the one (Sta. 228) is made recognizable only by the pigmentation in combination with the fact that a few of the conspicuous white ova are still intact, while the other—in a somewhat better state—is so battered that only one of the secondary tentacles is still to be seen, and none of the otocysts. Hence they add nothing to previous accounts based on better material.

Aegina.

***Aegina citrea* Eschscholtz.**

Aegina citrea, Eschscholtz, 1829, p. 113, Pl. 10, Fig. 3.

See Bigelow, 1938, p. 130, for the most recent discussion of this genus; Mayer, 1910, pp. 451-454, and Thiel, 1936, p. 73 ("*Ae. rosea*"), for lists of references to the various named representatives of *Aegina*, all of which probably refer to the one species, *citrea*.

Material: Sta. 210, 910-0 meters, 1 specimen about 17 mm. in diameter.

Sta. 230, 910-0 meters, 1 specimen about 22 mm. in diameter.

Both of these specimens are of the so-called "*rosea*" type, i.e., with the margins of the 8 adradial gastric pockets entire. A point still to be determined is the range of variation in number of otoliths that is normal for the species. In this connection it is interesting that in one quadrant of the specimen from Sta. 230 there are 14 of these organs—this probably being the complete number, since they are evenly spaced. This is somewhat fewer than recorded by Vanhöffen (1908a), namely, 16-20 per quadrant, but a larger number than reported by most other authors.

Beyond this, the present series calls for no special comment, for *Ae. citrea* has repeatedly been described and figured from specimens in better condition.

SCYPHOMEDUSAE.

CORONATA.

Periphyllidae.

Periphylla.*Periphylla hyacinthina* Steenstrup.

Periphylla hyacinthina, Steenstrup, 1837.

For synonymy and recent discussion see especially Mayer (1910, p. 544, "*P. hyacinthina*"), p. 546 ("*P. hyacinthina* forma *regina*"); Broch, 1913, p. 4; Stiasny, 1934, p. 342; and Bigelow, 1938, p. 155.

Material: Stas. 148, 158, 210, 225, 227, 228, 230, 233, 234; a total of 22 specimens from about 15 to about 150 mm. in diameter at the level of the coronal furrow, all in hauls from 910-0 meters.

It now seems certain that all known representatives of the genus *Periphylla* actually belong to a single species. It also seems established that in general the "*dodecabostrycha*" form (small; low-rounded bell; transparent peripheral zone), the "*hyacinthina*" form (peripheral zone pigmented, bell usually high-arched, pointed), and the "*regina*" form (dense pigmentation, low-domed bell) represent successive stages in growth. But it is still an open question whether every *Periphylla* (if it survives) normally passes from the "*hyacinthina*" stage into the "*regina*" stage, or in what degree this basic succession may be confused by individual variation as to development of pigment, and as to bell-shape in relation to size. The fact that the largest specimens among the considerable series collected by Dr. Beebe near Bermuda during the years 1929 and 1930 (Bigelow, 1938, p. 156) were less than 60 mm. in diameter (at level of coronal furrow) but still referable to the "*hyacinthina*" stage also suggests that certain populations may fail to develop beyond this, before they die. It is in fact likely that this may apply to a considerable percentage of the individuals among other populations, some of whose members do finally attain the "*regina*" stage. Stiasny (1934, p. 361) has pointed out that the latter (i.e., the largest adults) have as a rule been taken well out from any coast, whereas the distribution of the "*dodecabostrycha*" stage makes it likely that "the small stages of *Periphylla* have their origin on the continental slope or near the coast - - - and that they are driven into the open sea and sink slowly to greater depths." But such a tendency toward offshore dispersal can hardly explain the absence (or at least great scarcity) of large specimens near Bermuda, for the collection was made at a station as typically oceanic as one could ask; as much so certainly as the Indo-Pacific localities, where the "*regina*" stage has been taken, namely the Galápagos-Cocos Island region, the *Zaca* stations, and the Gulf of Aden (Maas, 1897; Bigelow, 1909; 1928; Vanhöffen, 1902). To what extent such variations may be correlated with seasonal differences between generations in a given region is equally a question for the future.

The most interesting feature of the present series is that it contains two large specimens, respectively about 85 mm. and about 110 mm. in diameter at the level of the coronal furrow, that agree very closely in low-rounded bell, rectangular pedalia, stout tentacular bases and dense pigmentation, with the specimens of the "*regina*" stage recently recorded by Stiasny (1934). The fact that in the 85 mm. specimen (alcoholic) the pedalia are rather sharply marked off from the coronal zone but that in the 110 mm. example (in formalin) and also in the largest of all (about 150 mm., fragmentary) they merge insensibly into the latter just as in the *Discovery* examples, is additional evidence (if any were needed) that characters that have been used as specific among medusae may actually represent nothing more than the results of different methods of preservation.

* Except where obviously rubbed off.

Atollidae.

Atolla.***Atolla wyvillei* Haeckel.**

Atolla wyvillei, Haeckel, 1880, p. 488; 1881, p. 113, Pl. 29, Figs. 1-9.

See Broch (1913, p. 13), Browne (1916, p. 203), Bigelow (1928, p. 505; 1938, p. 160), and Stiasny (1934, p. 365), for early synonymy, and Bigelow (1938, p. 162), for a recent summary of distribution.

Material: Stas. 210, 219, 225, 228, 230, 233, 234; 24 specimens, all in hauls from 910-0 meters. The series range in diameter from about 11 mm. to about 95 mm.

This series—all are in more or less fragmentary condition—adds little except by way of confirmation to what is already known of this cosmopolitan bathypelagic medusa. Neither do the records extend the known range, for *A. wyvillei* had already been recorded widespread in the eastern side of the Pacific, not only in low latitudes, but far to the north as well as far to the south of the areas crossed by the *Zaca*.

Among such of the *Zaca* series as are in good enough condition to show the state of the disc, it is more or less furrowed in eleven, but smooth in four, a considerably smaller proportion of smooth-disc'd than reported near Bermuda (Bigelow, 1938, p. 161), but almost precisely the same proportions as found by Kramp (1924) in the Mediterranean. However, various collections, combined, from the Antarctic (Stiasny, 1934), Mediterranean (Kramp, 1924), and from various localities in the North Atlantic (Broch, 1913; Bigelow, 1928; 1938) have contained about as many of one type as the other (230 smooth, 233 notched).

Unfortunately, the smallest specimens were not in good enough condition to show whether the gonads had appeared, as they commonly do by the time a diameter of 10 mm. is reached. The presence, however, of one specimen of 25 mm., in good condition but showing no trace of gonads, proves that some *Atollas* may reach a considerable size before the sexual organs appear; a retarded development for which no explanation is as yet forthcoming.

DISCOPHORA.

Pelagidae.

Pelagia.***Pelagia noctiluca* Forskål**

Medusa noctiluca, Forskål, 1775, p. 109.

For summary of synonymy, see Bigelow, 1938, p. 164.

Material: Stas. 219, 227, 230, 233, 234, and Gorgona Island, 34 specimens, about 20 mm. to about 75 mm. in diameter, in hauls at the surface and from 910-0 meters.

All of the smaller specimens are in very fragmentary condition. The two largest, however, (about 65 mm. and about 75 mm. in diameter) are well preserved.

These specimens of this cosmopolitan inhabitant of warm seas all fall well within the known limits of variation of *P. noctiluca*. In fact, it has yet to be proven that this does not apply to every specimen of *Pelagia* from whatever source, that has yet been critically examined. Hence, the general agreement, by recent authors (see especially Kramp, 1924; Stiasny, 1934; Bigelow, 1928; 1938) that the genus, as now known, is monotypic, and that

some designation other than "species" must be invoked to designate the numerous variations as to form and distribution of exumbrial nematocyst knobs, on which specific names have been based.

Stomolophidae.

Stomolophus.

Stomolophus illustrates the situation—not uncommon among medusae—where the Linnaean system of classification cannot adequately represent the existing facts, for while the named representatives of the genus differ widely, they are connected by so continuous a series of intermediates in all characters supposedly diagnostic that it appears impossible to define distinct species in the ordinary sense. And, correspondingly, the history of the genus has been one of alternate multiplication and reduction. Thus, Mayer (1910) reduced the five named forms to one species *meleagris* L. Agassiz and one variety of the latter (*fritillaria* Haeckel), while I (Bigelow, 1914) concluded that there was no reason to retain *fritillaria* even as a varietal name. Stiasny (1921; 1922), however, again separated *fritillaria* from *meleagris*, basing the distinction on form of the bell, number of marginal lappets and color, and especially on the form and size of the scapulettes which he considered a reliable anatomical character. More recently, however, he (Stiasny, 1931) has found from examination of excellent preserved specimens from British Guinea and Trinidad, that while extremes of the "*fritillaria*" and "*meleagris*" forms are far apart, all the characters formerly considered specific are so variable that he "der Bigelowischen Ansicht dass nur ein einziger ampla Species von *Stomolophus* besteht, nicht mehr so ablehnend gegenüber stehe als früher" (Stiasny, 1931, p. 175). The union of *meleagris* and *fritillaria* may therefore be allowed to stand, at least provisionally. Unfortunately, the present series does not afford any basis for the critical study that Stiasny (1922) thinks needful for eventual revision.

Stomolophus meleagris L. Agassiz.

Cephea rhizostoma, Gibbes, 1847, vol. 3, p. 183 (*non* Lamarck, 1817).

Stomolophus meleagris, L. Agassiz, 1860, Pl. 14, Figs. 1-8; 1862, p. 138, 151; A. Agassiz, 1865, p. 40; Haeckel, 1880, p. 599; Mayer, 1910, p. 710, Pl. 75, Pl. 76, Figs. 1-3; Bigelow, 1914, p. 240; Stiasny, 1921, p. 170; 1922, p. 57; 1922a, p. 499; Boone, 1933, p. 48, Pl. 10.

Stomolophus agaricus, Haeckel, 1880, p. 599.

Stomolophus fritillaria, Haeckel, 1879, Pl. 35, Figs. 1-9; 1880, p. 598; Von Lendenfeld, 1884, p. 292; Vanhöffen, 1888, p. 31, 42; Stiasny, 1921, p. 170; 1922, p. 55; 1931, p. 175.

Stomolophus meleagris var. *fritillaria*, Mayer, 1910, p. 711.

Stomolophus chunii, Vanhöffen, 1888, p. 31, Pl. 3, Figs. 4, 5, Pl. 4, Fig. 1; Trinci, 1906, p. 1.

Brachiolophus collaris, Haeckel, 1880, p. 597 (juv.).

Material: Sta. 220, surface, 1 specimen about 23 mm. in diameter.

Sta. 219, 540-0 meters, 1 specimen about 40 mm. in diameter.

The larger of these specimens is at about the stage pictured by Mayer (1910, Pl. 75, Fig. 2). They do not add anything of importance to the accounts of the young stages given by him, and by Stiasny (1922a).

Pacific localities of record for *Stomolophus meleagris* had already included the Bay of Panama (Vanhöffen, 1888), the coast of Costa Rica (Haeckel, 1880, as *S. agaricus*), and southern California (Bigelow, 1914).

It was therefore to be expected in the waters traversed by the *Zaca*. The genus is so far known only from the two coasts of America, North and South, in low and mid-latitudes.

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20.

Two New Species of Trematodes (*Apharyngostrigea bilobata*: Strigeidae, and *Cathaemasia nycticoracis*: Echinostomidae) from Herons, with a Note on the Occurrence of *Clinostomum campanulatum* (Rud.).^{1, 2}

O. WILFORD OLSEN³

(Plate I).

During the course of parasite examinations on black-crowned night herons (*Nycticorax nycticorax hoactli* (Gmelin)) and great blue herons (*Ardea herodias herodias* Linn.), originating from three widely separated rookeries in Minnesota, two new species of trematodes belonging to the families Strigeidae and Echinostomidae were collected.

FAMILY STRIGEIDAE.

A number of strigeid flukes collected from both the black-crowned night heron and great blue heron constitute a new species for which the name *Apharyngostrigea bilobata* n. sp. is proposed, the name being suggested by the bilobed character of the ovary.

***Apharyngostrigea bilobata* n. sp.**

Description: Body length 2.8-4 mm., forebody 0.766-1.33 mm. long by 0.633-0.8 mm. wide, hindbody 1.76-2.95 mm. long by 0.266-0.65 mm. wide. Forebody approximately cubic, hindbody cylindrical, narrowing somewhat posteriorly, caudal extremity truncated. Holdfast organ well developed, filling forebody, composed posteriorly of a cup-like structure with anterior half forming a smaller dorsal and a larger ventral lamella. Adhesive gland in posterior extremity of adhesive organ which is at junction of two body regions, strongly lobulated, posterior third composed of a single large piece, anterior two-thirds composed of numerous small lobes, shape longitudinally oval, size 160-266 μ wide by 240-333 μ long. Oral sucker 76-164 μ wide by 124-208 μ long; acetabulum 120-280 μ wide by 132-300 μ long; pharynx absent, oesophagus extends to level of anterior margin of acetabulum, intestinal crura extend along ventral surface of body to its caudal extremity. Testes tandem, multilobated, large, fill third quarter of body length, vasa efferentia unite at anterior margin of first testis forming the voluminous, convoluted proximal portion of vas deferens which narrows greatly in diameter, then passes caudad along median ventral surface of testes and forms large coiled

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² In cooperation with the Division of Game and Fish, Minnesota Conservation Department.

³ Resigned August 15, 1939, to enter the U. S. Bureau of Animal Industry, Zoological Division.

seminal vesicle which fills area between hind testis and genital cone, entering genital pore from dorsal side. Ovary smooth, transversely elongated, bilobated, with deep cleft in posterior margin, located near middle of body; width 180-483 μ , length 124-400 μ ; oviduct originates on posterior-ventral surface of ovary passing dorso-caudad through cleft to dorsal surface of latter where Laurer's canal is given off, then swings to left side of front testis and caudad along its lateral margin to Mehlis' gland. Ascending limb of uterus extends cephalad from Mehlis' gland along ventral side of anterior testis and ovary, rising to dorsal side of body at anterior margin of ovary and continuing cephalad to near holdfast gland where it bends caudad to form descending limb which passes along ventral side of body to genital cone, entering common genital duct from ventral side. Mehlis' gland lies between testes, dextrad from median line. Yolk reservoir median, at caudal margin of Mehlis' gland. Vitelline follicles large, spread over entire surface of body and lips of holdfast except dorsal to holdfast gland and reproductive organs and in ventral surface of forebody. Follicles fewer laterally in region of ovary and testes, more abundant ventrally and laterally between holdfast gland and ovary; they encircle body caudad from hind testis. Ova 56-64 μ wide by 83-88 μ long.

Host: Nycticorax nycticorax hoactli (Gmelin).

Ardea herodias herodias Linn.

Habitat: Small intestine.

Locality: Owatonna, Minnesota, U. S. A.

Type Specimen: U. S. Nat. Mus. Helm. Coll. No. 9279; paratype: 9280; also Helm. Coll. Div. Ent. and Eco. Zool., University of Minnesota.

DISCUSSION.

The genus *Apharyngostrigea* was erected by Ciurea (1927) to receive *Distoma cornu* Goeze (Zeder) 1800. Szidat (1929) added *A. brasiliana* Szidat, 1929, and *Distomum simplex* Johnston, 1904. In his description of *D. simplex*, Johnston (1904: 112) states "the oral and ventral suckers are large and equal in size . . .; the pharynx is smaller" but since his figures do not show a pharynx Szidat concluded that "Trotz dieser Bemerkung scheint auch bei dieser Art der Pharynx ganz zu fehlen, da Johnston 1904 ihn in seinen Figuren nicht abbildet." The correctness of Szidat's conclusion in regard to the absence of the pharynx on the grounds that it is not figured might justly be questioned and until an examination of Johnston's material has been made, *Distomum simplex* should be considered as a provisional member of the genus. Dubois (1938) included *Holostomum repens* Chase, 1921, from herons.

Subsequent to the appearance of Szidat's paper, the descriptions of four additional species of *Apharyngostrigea* have appeared. These, together with *Apharyngostrigea bilobata* n. sp., are included in the following key, which will serve to differentiate them. *A. bilobata* may be readily distinguished from all the known species by the strongly bilobated ovary with its deep posterior cleft.

KEY TO THE KNOWN SPECIES OF *Apharyngostrigea*.

- | | |
|--|-----------------------------------|
| 1. Testes with margins smooth or nearly smooth, rounded or ovoid | 2 |
| Testes with margins deeply lobated, variously shaped | 3 |
| 2. Testes very large, being 800 μ in diameter; oral sucker large, being 740 μ in diameter; from <i>Canceroma cochlearia</i> , Brazil | <i>A. brasiliana</i> Szidat, 1929 |
| Testes small, being 336-400 μ and 330-338 μ in diameter; oral sucker 180 μ in diameter; from cattle egret, India | <i>A. egretti</i> Verma, 1936 |

3. Testes bilobated, horse-shoe shaped; anterior limit of vitellaria at level of acetabulum, ovary and testes in posterior half of hindbody; from *Circus macrurus*, Syria *A. flexilis* Dubois, 1934
Testes multilobated, not horse-shoe shaped; ovary at middle of hindbody or cephalad 4
4. Oral sucker and acetabulum equal or about equal in size, ratio being as 1:1 - 1:1.1 .. 5
Acetabulum distinctly larger than oral sucker 6
5. Ovary near middle of hindbody, walls of hindbody nearly parallel, not bulged by testes; oral sucker and acetabulum equal in size; from *Noto-phox novae hollandiae*, Australia *A. (?) simplex* (Johnston, 1904)
Ovary in posterior portion of first quarter of hindbody; testes enormous in size with numerous lobes, causing hindbody to bulge greatly in two middle quarters; oral sucker slightly smaller than acetabulum, ratio as 1:1.1; from *Herodias timorensis*, Philippine Islands
A. garciai Tubanguui, 1933
6. Ovary bilobated, being deeply cleft on posterior margin; from *Nycticorax nycticorax hoactli* and *Ardea herodias herodias*, North America
A. bilobata n. sp. 7
Ovary not bilobated 7
7. Vitellaria do not reach to acetabulum; body large, being 6 mm. long; from *Noto-phox novae hollandiae* *A. repens* (Chase, 1921)
Vitellaria extend cephalad from acetabulum 8
8. Acetabulum about twice size of oral sucker; body large, being 6 mm. or more in length; from *Ardea cinerea* and *A. purpurea*, Europe
A. cornu Goeze (Zeder), 1800
Acetabulum not twice as large as oral sucker, ratio as 1:1.5; body small, up to 3.5 mm. long; from *Ardeola ibis ibis*, Egypt *A. ibis* Azim, 1935

FAMILY ECHINOSTOMIDAE.

Two specimens of flukes collected from one black-crowned night heron belong to the genus *Cathaemasia* Looss, 1899. The name *Cathaemasia nycticoracis* n. sp. is proposed.

***Cathaemasia nycticoracis* n. sp.**

Description: Body elongated with ends rounded, anterior end somewhat attenuated cephalad from acetabulum; length of body 5.3-5.4 mm., width at level of ovary 1.05-1.06 mm. Cuticle without spines. Oral sucker subterminal, 416 μ wide by 416-466 μ long. Acetabulum 700 μ wide by 633-650 μ long, located in anterior part of second quarter of body length. Prepharynx absent. pharynx 208-216 μ wide by 266-292 μ long; oesophagus 466 μ long, of uneven diameter, being strongly constricted in some parts while others are greatly distended, lined with intestinal epithelium; intestinal caeca extend to caudal end of body, with small evaginations of wall. Testes and ovary in third quarter of body length. Testes small, tandem, about equal in size, compact and with 6-9 short dendritic processes each, anterior testis 450 μ wide by 366-433 μ long, posterior testis 416-450 μ wide by 416-483 μ long. Cirrus retracted, seminal vesicle about 400 μ long by 128 μ in diameter. Genital pore median, at anterior margin of acetabulum. Ovary transversely elongated, separated from anterior testis by Mehlis' gland and seminal receptacle, 300-433 μ wide by 166-200 μ long; seminal receptacle oval, 216 μ wide by 150 μ long, located at posterior margin of ovary; Mehlis' gland at level of

and sinistrad from seminal receptacle; uterus short, its coils lie between ovary and acetabulum. Laurer's canal present. Vitellaria consisting of rather large follicles, extending from between caudal margin of acetabulum and ovary to posterior end of body. Caudad from hind testis, the follicles meet medially. Excretory vesicle with shallow, lateral evaginations. Ova 91-95 μ long by 42-53 μ wide.

Host: Nycticorax nycticorax hoactli (Gmelin), *Ardea herodias herodias* Linn.

Habitat: Small intestine.

Locality: Owatonna, Steele Co., Minnesota; Cheboygan County, Michigan (Michigan Biological Station).

Type Specimen: No. 9281 U. S. Nat. Mus. Helm. Coll.; paratype: Helm. Coll. Ent. and Eco. Zool., University of Minnesota, No. 4:14.

DISCUSSION.

In his discussion of the genus, Harwood (1936) pointed out the similarities existing between *Cathaemasia* Looss, 1899, and members of the family Echinostomidae in the nature of the excretory system and the presence of an epithelial rather than a cuticular lining of the oesophagus. For this reason, he transferred it from the family Cathaemasiidae Furhmann, 1928, back to the family Echinostomidae where Odhner (1926) had placed it originally. *Cathaemasia* together with *Mehlisia* Johnston, 1913, and *Stephanoproroides* Price, 1934, lack the spined collar of the other members of the family Echinostomidae.

Cathaemasia nycticoracis differs from all the known species of the genus in (1) the absence of cuticular scales, (2) in the very compact nature of the body of the testes, both of which are confined to the third quarter of the body length, and from which radiate simple, stubby branches, (3) the equatorial position of the ovary, and (4) the vitellaria fuse medially caudad from the hind testis. It resembles *C. reticulata* (Wright, 1879) in that the uterus is relatively short.

The following key, adopted from Harwood (1936), will further differentiate the species.

KEY TO THE SPECIES OF *Cathaemasia*.

1. Body without scales; ovary equatorial; testes with very short, simple branches radiating from large compact body, confined to third quarter of body length; vitelline follicles fuse medially caudad from hind testis; from *Nycticorax nycticorax hoactli* and *Ardea herodias herodias*, North America. *C. nycticoracis* n. sp.
Body scaled; ovary definitely pre- or postequatorial; testes consist primarily of long slender branches; extend into extreme posterior part of body 2
2. Ovary preequatorial; uterus relatively short; cuticular spines present on both ventral and dorsal surfaces, from *Megaceryle alcyon*, North America. *C. reticulata* (Wright, 1879)
Ovary postequatorial; uterus relatively long; cuticular spines confined to ventral surface. 3
3. Testicular branches relatively short; vas efferens from caudal testis passing to right; from *Ardea nigra*, Europe, and *Ciconia alba*, Africa. *C. hians* (Rud., 1809)
Testicular branches relatively long; vas efferens from caudal testis passing to left 4

4. Egg 160-170 μ long; from *Leptoptilus crumenifer*, Africa
C. spectabilis Odhner, 1926
 Egg 57-62 μ long; from *Tantalus ibis*, Africa *C. famelica* Odhner, 1926

NOTE ON THE OCCURRENCE OF *Clinostomum campanulatum*
 IN HERONS AND CORMORANTS.

The black-crowned night herons, totalling 49 altogether, consisted of both adult and juvenal birds taken during the course of several summers from rookeries in Ramsey and Steele Counties, Minnesota. The great blue herons, on the other hand, were much fewer, there being only 11 birds, originating from a rookery in Rice County. From the total of 60 herons examined, *Clinostomum campanulatum* occurred only four times, all of which were in the black-crowned night herons.

In addition to the herons, *Clinostomum campanulatum* was found in 6 of 18 double-crested cormorants, *Phalacrocorax auritus auritus* (Lesson) killed in Minnesota. This appears to be a new host record for *C. campanulatum*.

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EXPLANATION OF THE PLATE.

All drawings made with the aid of a camera lucida except Figs. 6 and 7, which were made free-hand.

PLATE I.

Fig. 1. Ventral view of *Cathaemasia nycticoracis*.

Fig. 2. Dorsal view of *Apharyngostrigea bilobata* from *Ardea herodias herodias*.

Fig. 3. Dorsal view of *A. bilobata* from *Nycticorax nycticorax hoactli*.

Fig. 4. Longitudinal section of *A. bilobata*.

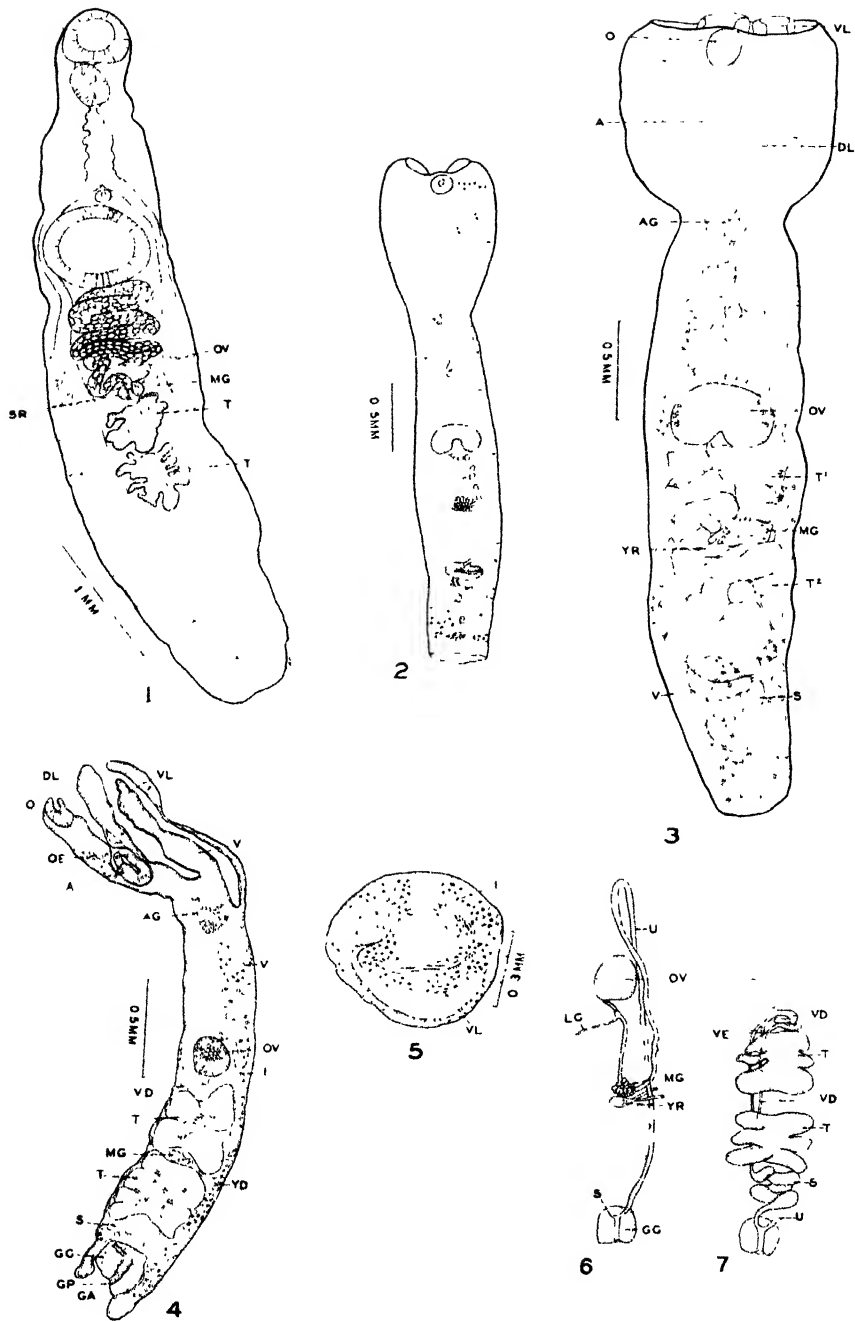
Fig. 5. Cross-section of *A. bilobata* taken a short distance cephalad from adhesive gland.

Fig. 6. Sinistral view of female reproductive system. Reconstructed.

Fig. 7. Sinistral view of male reproductive system. Reconstructed.

Key to Abbreviations.

A. acetabulum	OV. ovary
AG. adhesive gland	S. seminal vesicle
DL. dorsal lip	SR. seminal receptacle
GA. genital atrium	T. testes
GC. genital cone	U. uterus
GP. genital pore	V. vitellaria
I. intestinal caeca	VE. vas efferentia
LC. Laurer's canal	VD. vas deferens
MG. Mehlis' gland	VL. ventral lip
O. oral sucker	YD. yolk duct
OE. oesophagus	YR. yolk reservoir



TWO NEW SPECIES OF TREMATODES (APHARYNGOSTRIGEA BILOBATA STRIGLIDAE,
AND CATHAEMASIA NYCTICORACIS ECHINOSTOMIDAE) FROM HERONS, WITH A

21.

Nesting of the Sunfish, *Lepomis auritus* (Linnaeus), in
Tidal Waters.

NEIL D. RICHMOND

(Plate I).

During the summer of 1939, while the writer was making herpetological investigations in New Kent County, near Lanexa, Virginia, large numbers of sunfish nests were observed exposed at low tide along the shore of the Chickahominy River. These were all nests of *Lepomis auritus* (Linnaeus). On July 13, 1939, there being a low tide in the afternoon, the nests were photographed (Plate I) and examined more closely. At this time they contained eggs, in different stages of development, and hatchlings. Several nests were being constructed, and several were no longer in use, as could be seen by the accumulated silt. During low tide adult sunfish were not seen, although when the nests were submerged they could be seen swimming about in them.

The sites chosen for nesting were located where the bottom was of sand, not too deeply covered by mud and usually near some sheltering object such as a log (Pl. I, Fig. 1), stump, or as shown in Pl. I, Fig. 2, along the base of a retaining wall. In suitable locations the nests were grouped in large numbers, in some cases so closely that only the width of the rim separated them. This crowding was probably due to the areas suitable for nesting being very limited in this locality. The river is always turbid and all of the shallow water sheltered from wave and tide action has a mud bottom because of the rapid rate of silting, and is thus rendered unsuitable for nesting. Since all of the river has a mud bottom below the level of the normal low tide, there is left as the only possible nesting area a narrow strip of sand between the levels of the high and low tides on the more exposed portions of the shore. The proximity of the nests to the shore is apparently limited by the level of the lowest high tide; presumably the length of exposure above that level discouraged nest-building.

The normal rise and fall of the tides here is approximately two to three feet, but varies from day to day with a range of six feet between the extreme high tide and the extreme low. As the nests are all below the level of the lowest high tide, they are always submerged at least twice a day and on days when the tide is running high they may not be exposed at all. At other times only those nests nearest the shore are exposed. Thus the amount of the time that the nests are not submerged is extremely variable, the maximum exposure observed being about four hours with each low tide. This results in the nests being subjected to continually and rapidly changing environmental factors. When the low tide occurs during the afternoon, the nest is exposed to the direct rays of the sun and the shallow water remaining in it becomes warmer than that of the river, only to be abruptly cooled when the river returns. Equally variable is the depth of water over the nests, varying

from the four or five inches left in the nests at low tide to a maximum of five feet at extreme high tide. Slightly variable also is the salinity of the river, which, although normally fresh, becomes perceptibly brackish during any prolonged dry weather.

The dates on which nesting began and ended were not determined as the nests were present when these observations began, June 11, and were still there on August 4. However, on returning to this locality September 7, only the outlines of a few of the nests remained. A week later even they had disappeared, so it is probable that nesting ceased during the latter part of August. That these nests were successful under such conditions would seem to be implied by the presence of young fish in several of the nests.

EXPLANATION OF THE PLATE.

PLATE I.

- Fig. 1. Nests of *Lepomis auritus* in the Chickahominy River, Virginia, exposed at low tide.
- Fig. 2. Nests of *Lepomis auritus* in the Chickahominy River, Virginia, along a retaining wall, exposed at low tide.



FIG. 1



FIG. 2

NESTING OF THE SUNFISH *LEPOMIS A. RITUALIS* IN TIDAL WATERS

22.

Eastern Pacific Expeditions of the New York Zoological Society.
XXI. Notes on Echinoderms from the West Coast
of Central America.¹

HUBERT LYMAN CLARK

Museum of Comparative Zoology, Harvard University

(Plates I & II; Text-figures 1-4).

[This is the twenty-first of a series of papers dealing with the collections of the Eastern Pacific Expeditions of the New York Zoological Society made under the direction of William Beebe. The present paper is concerned with specimens taken on the Eastern Pacific *Zaca* (1937-1938) Expedition, which was made possible through the generosity of Mr. Templeton Crocker. For data on localities, dates, dredges, etc., refer to *Zoologica*, Vol. XXIII, No. 14, pp. 287-298.]

CONTENTS.

	Page		Page
Introduction	332	<i>Ophioneis annulata</i> (Leconte)	340
ASTEROIDEA		<i>Ophioneis nuda</i> Lütken & Mortensen	340
<i>Astropecten armatus</i> Gray	332	<i>Ophiocoma aethiops</i> Lütken	341
<i>Luidia asthenosoma</i> Fisher	332	<i>Ophiocoma alexandri</i> Lyman	341
<i>Luidia bellonae</i> Lütken	332	<i>Ophiopteris papillosa</i> (Lyman)	341
<i>Luidia foliolata</i> Grube	333	<i>Ophioderma panamense</i> Lütken	341
<i>Luidia ludwigi</i> Fisher	333	<i>Ophioderma teres</i> (Lyman)	342
<i>Oreaster occidentalis</i> Verrill	333	<i>Ophioderma variegatum</i> Lütken	343
<i>Nidorellia armata</i> (Gray)	333	<i>Diopederma danianum</i> (Verrill)	343
<i>Patiria minata</i> (Brandt)	333	<i>Schizoderma dylax</i> Nielsen	343
<i>Linckia colombiae</i> Gray	334	<i>Ophiura lutkeni</i> (Lyman)	343
<i>Pharia pyramidata</i> (Gray)	334	<i>Ophiozona pacifica</i> (Lütken)	344
<i>Phataria unifascialis</i> (Gray)	334	Genus <i>Ophiolepis</i>	344
<i>Othulia aculeata</i> Gray	334	<i>Ophiolepis variegata</i> Lütken	344
<i>Sclerasterias alexandri</i> var. <i>crassa</i> var. nov.	335	<i>Ophiolepis fulva</i> sp. nov.	345
		<i>Ophiolepis grisea</i> sp. nov.	346
OPHIUROIDEA		ECHINOIDEA	
<i>Ophiomyra panamensis</i> Lütken & Mortensen	336	<i>Eucidaris thouarsii</i> (Agassiz & Desor)	347
<i>Sigsbeia lineata</i> Lütken & Mortensen	336	<i>Styloridaris dubia</i> (H. L. Clark)	347
<i>Amphiura arcystata</i> H. L. Clark	336	<i>Astropyga pulvinata</i> (Lamarck)	348
<i>Amphipholis geminata</i> (Leconte)	336	<i>Arbacia incisa</i> (A. Agassiz)	348
<i>Amphipholis platydisca</i> Nielsen	337	<i>Lytechinus anamesus</i> H. L. Clark	348
<i>Amphipholis squamata</i> (delle Chiaje)	337	<i>Lytechinus pictus</i> (Verrill)	348
<i>Amphichondrius granulatus</i> Nielsen	337	<i>Tozopneustes roseus</i> (A. Agassiz)	349
<i>Amphiodia sculptilis</i> F. Ziesenhenné	337	<i>Strongylocentrotus purpuratus</i> (Stimpson)	349
<i>Amphiodia urtica</i> (Lyman)	338	<i>Echinometra vanbrunti</i> A. Agassiz	349
<i>Amphiodia vicina</i> sp. nov.	338	<i>Clypeaster europacificus</i> H. L. Clark	349
<i>Ophiactis savignyi</i> (Müller & Troschel)	339	<i>Clypeaster ochrus</i> H. L. Clark	350
<i>Ophiactis simplex</i> (Leconte)	340	<i>Clypeaster speciosus</i> Verrill	350
<i>Ophiothrix spiculata</i> Leconte	340	<i>Moiria clotho</i> (Michelin)	350
<i>Ophiothela gracilis</i> Nielsen	340	<i>Plagiobrissus pacificus</i> sp. nov.	351
		<i>Meoma grandis</i> Gray	352
		<i>Lovernia cordiformis</i> A. Agassiz	352

¹ Contribution No. 602, Department of Tropical Research, New York Zoological Society.

INTRODUCTION.

Aside from the holothurians, which I have not examined, the collection of Echinoderms which the *Zaca* made in 1937-38 consists of 822 specimens of 57 species, of which 73 specimens are sea-stars, 645 are brittle-stars and 104 are echini. Most of these are common forms and call for little comment, but a few are of notable interest and deserve a critical report. At least 4 species seems to be new to science, and 2 varieties are also treated as new.

It is a pleasure to thank Dr. William Beebe for the opportunity of studying this collection and for its deposit in the Museum of Comparative Zoology.

ASTEROIDEA.

***Astropecten armatus* Gray.**

Gray, 1840. *Ann. Mag. Nat. Hist.*, 6, p. 181.

There are 24 specimens of this common sea-star from a dozen stations between Manzanillo, Mexico, and Hannibal Bank, Panama, in 2.5-60 fms. of water. Most of them are small, $R=12-42$ mm., but several have R exceeding 100 mm. and a notable specimen from Port Culebra, Costa Rica, has $R=200-210$ mm. This big one is dark yellowish-brown above and below, but the adambulacral armature and the tips of the superomarginal spines are conspicuously lighter. In this individual the superomarginal spines are fully developed, a complete double series extending from the interradial line to the tip of each ray. In no other adult specimen are both series complete, and much diversity is shown in their development. One small specimen ($R=42$ mm.) taken 14 miles south of Judas Point, Costa Rica, is very nearly referable to *A. californicus*, as the superomarginal spines are confined to the interbranchial arcs and there is a single pair only in each arc, the first superomarginal in each series having one small erect spinelet.

Geographical Distribution: San Pedro, California, to Punta Santa Elena, Ecuador; low water to 80 fms.

***Luidia asthenosoma* Fisher.**

Fisher, 1906. *Proc. Wash. Acad. Sci.*, 8, p. 124.

This species was not taken by the *Zaca* in 1936 but there is a single small specimen in the present collection, from Hannibal Bank, Panama, in 35-40 fms. The rays are only about 23 mm. long and 6 mm. wide. The color above is pale brown, variegated with whitish; beneath it is nearly white.

Geographical Distribution: Monterey, California, to Los Coronados Islands, L.C., Mexico; 11-339 fms.

***Luidia bellonae* Lütken.**

Lütken, 1865. *Vid. Med. Dansk. Nat. Foren.* 1864, p. 133.

There are 2 small but typical specimens of this species; one with $R=75$ mm., from 16 fms. in Chamela Bay, Mexico, and one, with $R=100$ mm., from 30 fms. off Manzanillo, Mexico.

Geographical Distribution: Gulf of California to Iquique, Chile; also Galápagos Islands; 2-30 fms.

***Luidia foliolata* Grube.**

Grube, 1866. *Jahresber. schles. Ges. Vaterl. Cultur.* 1865, p. 59.

There are a dozen specimens of this well-known Californian species. The largest has $R=140$ mm. and $br=27$, but the others are much smaller and several are very badly damaged. They were taken at various stations between Tenacatita Bay, Mexico, and Corinto, Nicaragua, in 2-30 fms.

Geographical Distribution: Southeastern Alaska to Mazatlan, Mexico; 2-189 fms.

***Luidia ludwigi* Fisher.**

Fisher, 1906. *Proc. Wash. Acad. Sci.*, 8, p. 122.

This interesting species is represented by 2 specimens taken east of Cedros Island, Lower California, in 45 fms. (St. 126 D-13, -14). In one $R=$ only 37 mm. but the larger one has $R=100$ mm. They are alike in color, a reddish fawn, deepest along median area of each ray. It is interesting to note that the Zaca in 1936 secured 4 species of *Luidia* but although in 1937-38 she again took 4 species of the genus, only 2 are common to both collections.

Geographical Distribution: Monterey Bay to San Pedro, California; 15-50 fms.

***Oreaster occidentalis* Verrill.**

Verrill, 1867. *Trans. Conn. Acad.*, 1, p. 278.

There are 3 specimens of this common species, 1 from a trap at Guatulco, Mexico, and 2 from Port Parker, Costa Rica. All are of moderate size with $R=100-110$ mm.

Geographical Distribution: Lower California to Ecuador; also Cocos and Galápagos Islands; low water to 50 fms.

***Nidorellia armata* (Gray).**

Pentaceros armatus Gray, 1840. *Ann. Mag. Nat. Hist.*, 6, p. 277.

Nidorellia armata Verrill, 1867. *Trans. Conn. Acad.*, 1, p. 280.

Besides a normal 5-rayed specimen, with $R=90$ mm., from St. 200 D-28-30, at Corinto, Nicaragua, in 3 fms., there is a slightly smaller specimen from the same station, which has 5 rays orally but from above seems to have 6 rays; one ambulacral furrow when about 8 mm. from the mouth forks and a ray has developed in association with each division. These 2 rays, however, are only about 50 mm. long, while the 4 other rays have $R=83$ mm.

Geographical Distribution: Guaymas, Mexico, to Zorritos, Peru; also Galápagos Islands; low water to 40 fms.

***Patiria miniata* (Brandt).**

Asterina miniata Brandt, 1835. *Prodromus*, p. 68.

Patiria miniata Verrill, 1914. *Harriman Exp. Sea-stars*, p. 264.

This northern species is represented by a single very small specimen taken at St. 126 D-19, southeast of Cedros Island, Lower California, in 25 fms. It has 5 rays, with $R=8$ mm. and might well be called in the *Asterina* stage.

Geographical Distribution: Sitka, Alaska, to Gulf of California; low water to 165 fms.

***Linckia colombiae* Gray.**

Gray, 1840. *Ann. Mag. Nat. Hist.*, 1, p. 285.

A single small 6-armed specimen, scarcely 5 mm. across the disk but with $R=40$ mm., more or less, represents this common species. It was taken, with the preceding, at St. 126 D-19, southeast of Cedros Island, Lower California, in 25 fms.

Geographical Distribution: San Pedro, California, to Colombia; also Galápagos Islands; low water to 55 fms.

***Pharia pyramidata* (Gray).**

Ophidiaster pyramidatus Gray, 1840. *Ann. Mag. Nat. Hist.*, 1, p. 284.

Pharia pyramidata Sladen, 1889. "Challenger" *Asteroidea*, p. 784.

A half a dozen specimens with R ranging from 50 to 90 mm., were taken at Tenacatita and Sihuatanejo Bays, Mexico, and Port Parker and Uvita Bay, Costa Rica.

Geographical Distribution: Gulf of California to Zorritos, Peru; also Galápagos Islands; low water to 10 fms.

***Phataria unifascialis* (Gray).**

Linckia unifascialis Gray, 1840. *Ann. Mag. Nat. Hist.*, 1, p. 285.

Phataria unifascialis Sladen, 1889. "Challenger" *Asteroidea*, p. 786.

Of the 14 specimens, with R ranging from 15 to 87 mm., few call for comment. They were taken at Tenacatita and Sihuatanejo Bays, Mexico; Cardon Isl. at Corinto, Nicaragua; Uvita Bay, Costa Rica, and Bahía Honda, Panama. The specimen from Corinto is a very fine one with $R=87$ mm. and $br=11$. The one from Uvita Bay is very odd, for each ray has been bitten or broken off at the tip and then more or less regenerated; the longest is only 46 mm. long but it is 12 mm. broad. The color is definitely yellow.

Geographical Distribution: Gulf of California to Zorritos, Peru; also Galápagos Islands; low water to 10 fms.

***Othilia aculeata* Gray.**

Gray, 1840. *Ann. Mag. Nat. Hist.*, 1, p. 281.

Plate I, figs. 1 & 2.

At Corinto, Nicaragua, St. 200 D-5,-6,-7, in 2-2.5 fms., the *Zaca* dredged 4 specimens of an echinasterid, which are apparently examples of this long lost species. Although described almost a century ago it has never since been taken and no specimens are known to be extant. It is therefore extraordinarily interesting that the *Zaca* should have secured these 4 individuals. Gray's specimens were from Guacamayo, Central America, fine sand, 13 fms., and apparently were larger than any of these from Costa Rica. As he gives no measurements, however, and only a very brief and imperfect description, much has to be inferred in regard to the types. It is worth while therefore to give some details about the *Zaca* specimens.

The smallest specimen, now dry, has $R=14$ mm.; $r=3$ mm. and br is the same. There are 6 relatively large spines on the disk, the central one the smallest. On each ray there are about 7 such spines in three indefinite series of 2 or 3 each. Many minute spinelets are scattered here and there, mostly on the distal half of each arm. All the larger skeletal plates have, in this dry specimen, a shagreen-like surface. Color light gray-brown with the tips of the large spines and the lower surface pale yellow.

A second specimen has $R=21$ mm. with $r=5$ mm. and $br=4.5$. The color is as in the smaller specimen. There are about 5 big spines in each of three series on each arm, and 4 or 5 similar but somewhat smaller spines on the disk. There are very few minute spinelets except near tip of each arm.

The third specimen is nicely preserved in alcohol. It has $R=28-30$ mm., $r=7$, $br=6$. The body surface is very smooth with scarcely any small spinelets except at very tip of arm and here and there on oral surface of distal part of arm. There are about 20 of the big spines on each ray, and 7 or 8 on the disk. On the rays there are marginal series of 5 or 6 spines, an irregular median dorsal and an incomplete lateral on each side; these 3 series having 3-5 spines each. The color is quite different from the dried specimens; it is more or less definitely brown on the sides of the arms, where it is darkest, but dorsally it is fawn-color and orally nearly buff or yellowish; the spines are lightest at tip.

The largest specimen (Plate I, figs. 1 & 2) is dried from alcohol and its color is dull yellow-brown with the papular areas a darker brown. $R=33-35$ mm., $r=8$ and br is also 8. There are about 5 rather indefinite series of big, nearly white, spines (2-5 mm. long) on each ray. Papulae are conspicuous; on the oral surface they chiefly occur singly; on sides of ray, there are 2 or 3 in a group, while aborally there are up to 8-10 in each area. Aborally there are a very few widely scattered minute spinelets; 6-8 of these are on the carinal ridge at the very tip of each arm. On distal half of arm there are a very few small spines scattered on the sides and oral surface. Adambulacral spines in 3 more or less distinct series; innermost, minute curved spinelets well up in furrow; on furrow margin a series of pointed spinelets, a millimeter long; outside these is a series of similar but frequently stouter spinelets, but this series is not so nearly complete as the marginal one.

Although these specimens are probably all young, they are noticeably distinct from any of the better known sea-stars of the Panamic region. The largest was submitted to Dr. W. K. Fisher, the world's authority on sea-stars, who kindly had the best possible photographs made (by Mr. B. B. Fisher) and permits me to publish them herewith. He believes it is justifiable to refer these specimens to Gray's long-lost species. Mr. Dilwyn John, of the British Museum, assures me that Gray's specimens are no longer extant, although their fate is unknown. They are described as having 7 series of large spines on the arms, indicating that they were considerably larger than the largest of the *Zaca* quartette, as previously stated. All efforts to locate "Guacamayo" have proved futile but as Gray states that Hugh Cuming, Esq., was the collector, and Cuming is not known to have collected on the eastern coast of Central America, we are justified in believing that the original specimens of *aculeata* were from the western coast.

Geographical Distribution: Prior to *Zaca* collection, known only from a single station on the western coast of Central America, the location of which is unknown.

***Sclerasterias alexandri* var. *crassa* var. nov.**

A single small sea-star from St. 126 D-19, southeast of Cedros Island, Lower California, in 25 fms. caused me so much perplexity that I sent it to Dr. Fisher who very kindly made a careful study of its important features and wrote me: "I would list this as a variation of *S. alexandri*." It differs "from the type of *alexandri* in having coarser spines and constantly diplacanthid adambulacrals." However "the coarseness of spines is usually quite variable in *Coscinasterinae*." "There is a well-developed web between outer inferomarginal spines which in *S. heteropaes* is practically absent. The

crossed pedicellariae are like those of *alexandri* in size and shape." In color, "*heteropaes* is gray-green; *alexandri*, red-brown."

This interesting specimen, which may be designated as the holotype of var. *crassa* (M.C.Z. No. 3753) has a disk 6 mm. across and short, stout arms only 20 mm. long, 4 mm. in actual diameter at base, but 7 mm. wide on the actinal side, when the inferomarginal spines are included. As in typical *alexandri* there are but 3 series of abactinal spines, a carinal and on each side a superomarginal. These spines are shorter, stouter and blunter than in typical *alexandri*. The skeleton is much coarser and the papular areas very much smaller and less conspicuous than in the cotypes of *alexandri* with which it has been compared. The color is a deep red-brown above, much darker than these types. These differences combine to give it a markedly different facies from that of Ludwig's types. As there is but one specimen, however, and that obviously young, it seems best to list it simply as a variety, but more and larger specimens will probably justify its recognition as a distinct species. It is strikingly different from *heteropaes*, the only other *Sclerasterias* from the western coast of America.

Geographical Distribution: Bay of Panama; 52-210 fms. The variety *crassa* is known only from the *Zaca* specimen.

OPHIUROIDEA.

***Ophiomyxa panamensis* Lütken & Mortensen.**

Lütken & Mortensen, 1899. *Mem. M.C.Z.*, 23, p. 182.

At Station 126 D-19, off Cedros Island, Lower California, in 25 fms. of water, 4 small adults of this brittle-star were taken, while a very young one, only 5 mm. across the disk, was collected at St. 224 D-1,-2,-3, on Hannibal Bank, Panama, in 35-40 fms.

Geographical Distribution: Gulf of California to Panama; also Cocos and Galápagos Islands; 25-85 fms.

***Sigsbeia lineata* Lütken & Mortensen.**

Lütken & Mortensen, 1899. *Mem. M.C.Z.*, 23, p. 183.

A single small adult was collected at St. 224 D-2,-3, on Hannibal Bank, Panama, in 35 fms. It is nearly white now, but the brown lines on the disk can still be detected.

Geographical Distribution: Cocos and Galápagos Islands; 30-100 fms.

***Amphiura arcystata* H.L. Clark.**

H. L. Clark, 1911. *Bull.* 75, U.S.N.M., p. 145 (printed *acrystata* by error).

A very small specimen, 4.5 mm. across the disk, was dredged in 38 fms., off Maldonado Point, Mexico, at St. 192 D-3. It is now white with the naked skin of the disk, yellowish-brown.

Geographical Distribution: Japan and California to Gulf of California; 30-330 fms.

***Amphipholis geminata* (Leconte).**

Ophiolepis geminata Leconte, 1851. *Proc. Acad. Nat. Sci. Phila.* 5, p. 317.

Amphipholis geminata Ljungman, 1867. *Öfv. Kongl. Vet. Akad. Förh.*, 23, p. 313.

This very long-armed brittle-star seems to be common in the Gulf of Fonseca, El Salvador, and in the Gulf of Nicoya, Costa Rica. There are 27 specimens at hand from St. 199 D-1,-17-25, and 3 from St. 213 D 13-17. A muddy bottom in shallow water is the chosen habitat.

Geographical Distribution: Panama (Pacific side); low water to 5 fms.

***Amphipholis platydisca* Nielsen.**

Nielsen, 1932. *Vid. Med.* 91, p. 290.

There are 11 specimens of this fine big *Amphiodia*-like species, taken at the same stations as the preceding; St. 199 D-7-16; St. 213 D-12-17; and St. 214 D-1-4. Only 3 have the disk which is about 10 mm. across, still attached to the mouth frame and the smallest of these is a typical example of Nielsen's variety *microplax*. It is odd that Nielsen did not realize that his supposed variety is based on an individual with a regenerating disk.

Apparently *platydisca* is one of those amphiuroids which shed the disk, when mature, on very slight provocation. It may be that the shedding is the normal process of setting free ova and spermatozoa. But, at any rate, the present series of specimens shows that at the time and place when they were taken shedding was twice as frequent as retention. Nielsen's material was from Panama, so that the present series extends the range considerably to the northward.

Geographical Distribution: Panama (Pacific side); low water to 15 fms.

***Amphipholis squamata* (delle Chiaje).**

Asterias squamata delle Chiaje, 1828. *Mem. Anim. sans Vert. Napoli*, 3, p. 74.

Amphipholis squamata Verrill, 1899. *Trans. Conn. Acad.* 10, p. 312.

This small but wellnigh ubiquitous brittle-star is represented by a young individual from St. 126 D-19 (Lower California, southeast of Cedros Island, 25 fms.) and a still smaller specimen, only 2 mm. across the disk from *Pocillopora* coral, Jasper Island, Gulf of Nicoya, Costa Rica, 1 fm.

Geographical Distribution: Cosmopolitan; low water to 100 fms.

***Amphichondrius granulatus* Nielsen.**

Nielsen, 1932. *Vid. Med.*, 91, p. 304.

At St. 192 D-3, off Maldonado Point, Mexico, in 38 fms. on a muddy bottom, 2 specimens of this interesting species were taken. The larger is only 5 mm. across the disk and hence is little more than half grown but the generic features are unmistakable.

Geographical Distribution: The species was known hitherto only from the vicinity of La Jolla and San Diego, California.

***Amphiodia sculptilis* F. Ziesenhenné.**

F. Ziesenhenné, 1940. *Allan Hancock Pac. Exp.*, 8, No. 2, p. 24.

A single young specimen of this fine species was taken at St. 200 D-1,-3,-8, in 2-6.6 fms. at Corinto, Nicaragua, on a mangrove-leaves bottom. It was previously known from various stations on the western coast of Mexico. This individual is about 3.5 mm. across the disk and the arms are some 25 mm. long. The general color is dark gray but the oral region and the accompanying arm spines are cream. The single large tentacle scale is very distinctive.

Geographical Distribution: Western coast of Mexico; 5-20 fms.

***Amphiodia urtica* (Lyman).**

Amphiura urtica Lyman, 1860. *Proc. Boston Soc. Nat. Hist.*, 7, p. 258.

Amphiodia urtica Verrill, 1899. *Trans. Conn. Acad.*, 10, p. 313.

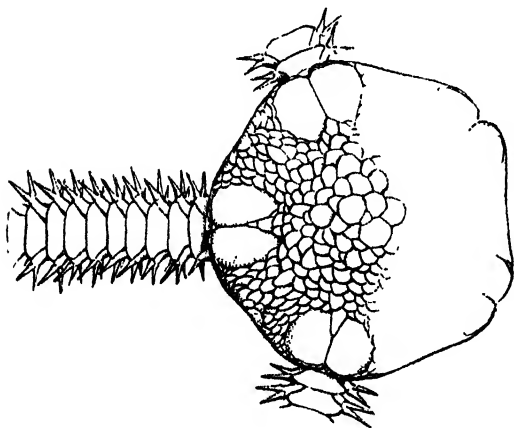
A single adult specimen, 6.5 mm. across the slightly elevated disk, was taken at St. 196 D-14, in Tangola-Tangola Bay, Mexico, in 5 fms. on a shelly bottom, thus extending the range considerably to the south.

Geographical Distribution: Shumagin Islands, Alaska, to Lower California; 15-50 fms.

***Amphiodia vicina*² sp. nov.**

(Text-figures 1 & 2).

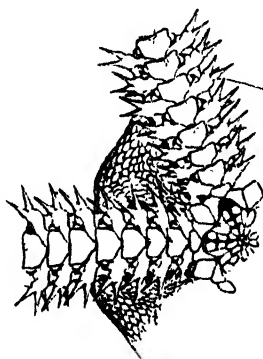
Disk 10 mm. in diameter, nearly circular and rather flat. Arms 5, 80-90 mm. long, rather stout basally, about 2 mm. wide regardless of the arm-spines, tapering very gradually to the not very attenuate tip. Disk covered by a coat of rather coarse overlapping scales without clearly indicated primary plates; the largest ones more than half a millimeter across; very few are even approximately circular, some are quite angular and some distinctly elongated; in each interradius there are 7-9 series separating the pairs of radial shields. These shields are about 3 mm. long, 1.5 mm. wide distally; they are in contact for one-half or more of their inner margins but proximally are separated by one large, long triangular scale or by 2 or more smaller ones. Upper arm-plates wider than long; basally the width is almost thrice the length and even far distally the length does not quite equal the width. On the basal part of the arm, the distal margin of each plate is much longer than the proximal, the resulting lateral angles being more or less rounded, although often very acute, and more or less of the upper end of the side arm-plates being conspicuous between them. On the basal part of the arm there is a slight but usually rather distinct keel or ridge along the mid-line.



Text-figure 1.

Amphiodia vicina. Upper surface.

× 6.



Text-figure 2.

Amphiodia vicina. Lower surface.

× 6.

Interbranchial areas closely covered, like the disk, by coarse overlapping scales; the uppermost or marginal scales stand on edge and form a low marginal "fence" around the disk, somewhat suggestive of *Ophiophragmus*; genital slits long, reaching nearly to the disk margin. First under arm-plate

² *vicinus* = neighboring, in reference to its nearness to *A. psara*, both structurally and geographically.

small, rounded, swollen, rather wider than long; second and succeeding plates rounded pentagonal, wider than long; the second and third plates have the lateral and distal margins concave, but this is not evident on the following plates; these plates are not quite in contact, yet the side arm-plates seldom meet in the mid-line; as a consequence there is generally the indication of a pit in the mid-line between the under arm-plates; the basal plates, especially the second and third, have the margins thickened or even a little swollen. Side arm-plates rather large and projecting but they do not actually meet either above or below, even distally; each carries 3 arm-spines, about a millimeter long, subequal or the middle one a little the longest; slightly swollen at base but tapering somewhat abruptly to a slender, if not acute, point. Tentacle-scales 2, rather large, subequal; as usual in such cases one is borne on the under arm-plate and one on the side arm-plate.

Oral shields spear-head shaped, longer than wide, with scarcely rounded angles, the madreporite a trifle larger than the others and slightly swollen. Adoral plates trigonal, slightly swollen, just meeting within, the inner margin concave, the other two straight. Oral papillae 3 on each side; those at the apex of the jaw are narrow and notably longer than wide, quite separated from each other; the second papilla tends to show some diversity in form, being flattened and somewhat angular, or rounded and scale-like, about as wide as long; the distal papilla is largest and most scale-like and is carried on the adoral plate. Teeth few, small and block-like.

Color of preserved specimens, now dry, light gray with a lavender tint, variegated with light cream-color or white; many disk scales are white in the holotype and in the smallest specimen but this is less evident in the others; each radial shield has a more or less conspicuous blotch of white or whitish on the distal half; oral surface very light; the under arm-plates and arm spines nearly white.

Holotype, M.C.Z. No. 6026, from St. 213 D-13, off Ballenas Bay, Gulf of Nicoya, Costa Rica, 35 fms., mud.

There are 12 paratypes from the same locality, (St. 213 D-13,-14,-15,-16; 35-45 fms.). One of these is remarkable for being symmetrically tetramerous; as the arms are 100 mm. long, it is obviously a large adult, but as the disk is missing little more can be said about it; the characters shown by arms and mouth-parts are entirely like those of the holotype. Another specimen worthy of mention is the smallest. It has a disk 7 mm. across with the scales scarcely overlapping and hence smoother and flatter than in the large individuals.

This is a well-marked species for while it reminds one of *psara* (H. L. Clark, 1935. *Ann. Mag. Nat. Hist.* (10) 15, p. 127) the difference in the upper arm-plates is very striking, and the arm-spines and under arm-plates are also different. Furthermore the oral papillae of *psara* are much stouter and the distal one in particular is much larger than in *vicina*. Whether the areas occupied by the two species overlap remains to be seen. So far as I know, *psara* has not been taken south of Acapulco.

Geographical Distribution: Known only from the *Zaca* collection.

***Ophiactis savignyi* (Müller & Troschel).**

Ophiolepis savignyi Müller & Troschel, 1842. *Sys. Ast.* p. 95.

Ophiactis savignyi Ljungman, 1867. *Öfv. Kongl. Vet. Akad. Förh.*, 23, p. 323.

This very common brittle-star is represented by 17 specimens, mostly small, but several of those taken at St. 195 D-5, are adults 6 mm. across disk, although all of this lot regardless of size have 6 arms. All of the material

was collected at St. 195 in Port Guatulco, Mexico, save 2 small specimens found at Cardon Island, Corinto Bay, Nicaragua.

Geographical Distribution: Tropicopolitan; low water to 27 fms.

***Ophiactis simplex* (Leconte).**

Ophiopsis simplex Leconte, 1851. *Proc. Acad. Nat. Sci. Phila.*, 5, p. 318.

Ophiactis simplex Lütken, 1859. *Add. ad Hist. Oph.* pt. 2, p. 130.

There are 4 very young specimens of this little *Ophiactis* from St. 126 D-19, east of Cedros Island, Mexico, in 125 fms.

Geographical Distribution: La Jolla, California, to Balboa, Canal Zone; low water to 5 fms.

***Ophiothrix spiculata* Leconte.**

Leconte, 1851. *Proc. Acad. Nat. Sci. Phila.*, 5, p. 318.

There are 78 specimens of this very common brittle-star, the largest 12 mm. across the disk. Most of them are dull gray-blue or purplish but those from St. 184 are very light colored, a pale grayish-brown, and those from St. 126 are also very light but with a reddish tint, the disk quite rosy or in the largest one a deep crimson in sharp contrast to the arms. This species was taken at the following stations: 126 D-19, southeast of Cedros Island, Mexico, 25 fms.; 184 D-2, off Manzanillo, Mexico, 30 fms.; 199 D-7-16, La Union, El Salvador, 5-6 fms.; 200 D-5-7, 28-30, Corinto, Nicaragua, 2-3 fms.; 218 D-5, Golfito, Costa Rica, 6 fms. There are 50 specimens taken from *Pocillopora* coral, Jasper Island, Gulf of Nicoya, Costa Rica, 1 fm.

Geographical Distribution: Monterey Bay, California, to Bay of Sechura, Peru, also Galápagos Islands; low water to 45 fms.

***Ophiothela gracilis* Nielsen.**

Nielsen, 1932. *Vid. Med.*, 91, p. 256.

There are 3 small 5-armed *Ophiothelas* which I refer with some hesitation to this species, on small fragments of a gorgonian from a tide-pool at Uvita Bay, Costa Rica. The largest is only 2 mm. across the disk. The genus needs critical study and revision.

Geographical Distribution: Panama; 4-5 fms.

***Ophionereis annulata* (Leconte).**

Ophiopsis annulata Leconte, 1851. *Proc. Acad. Nat. Sci. Phila.* 5, p. 317.

Ophionereis annulata Lyman, 1860. *Proc. Bost. Soc. Nat. Hist.*, 7, p. 203.

Half a dozen specimens were taken at Uvita Bay, Costa Rica, and a single specimen at Bahia Honda, Panama.

Geographical Distribution: San Diego, California, to Panama; also Galápagos Islands; low water to 20 fms.

***Ophionereis nuda* Lütken & Mortensen.**

Lütken & Mortensen, 1899. *Mem. M.C.Z.*, 23, p. 163.

A single small specimen, scarcely 5 mm. across the disk, was taken at St. 224 D-1, -2, -3, on Hannibal Bank, Panama, in 35-40 fms.

Geographical Distribution: Isabel Island, Mexico, to Gulf of Panama; also Galápagos Islands; low water to 85 fms.

***Ophiocoma aethiops* Lütken.**

Lütken, 1859. *Add. ad Hist. Oph.*, pt. 2, pp. 141, 145.

There is an adult specimen of this abundant Panamic brittle-star taken from coral, Arriba Isthmus, Port Parker, Costa Rica. It is 20 mm. across the light gray disk, which is irregularly speckled with deep brown. A small adult with all arms broken off near the base but each obviously regenerating, and 2 young specimens were collected in Bahia Honda, Panama. There are 9 specimens from St. 195 D-15, in Port Guatulco, Mexico, 1.5 fms., and there is a single specimen from an unknown station.

Geographical Distribution: Lower California to Panama; also Cocos and Galápagos Islands; low water to 10 fms.

***Ophiocoma alexandri* Lyman.**

Lyman, 1860. *Proc. Boston Soc. Nat. Hist.*, 7, p. 256.

This common long-armed brittle-star is represented by two lots of quite different appearance. From an unknown station, there are 9 adults, 10-15 mm. across the disk, with the usual brown coloration, the arms banded with a darker shade. There is no indication of green. The other lot was taken at St. 195, D-15, in Port Guatulco, Mexico, 1.5 fms., and consists of 22 specimens, ranging from 5 to 15 mm. across the disk with arms 7 times as much. They are notable for their unusual coloration. In the smallest specimen, the ground color is a very deep green, lightest near arm-tips, with more or less indefinite markings of a light shade. In larger specimens the disk is more brown and in the adults it is a definite uniform brown, (in one case almost deep yellow) with a green tinge around the margin. The arms are brown at base but green distally, irregularly but definitely banded with a darker shade. The shade and extent of the green show great diversity in different individuals, but the arm-spines are in all cases quite green with the tips often perceptibly lighter. The under arm-plates are green (or at base of arms, brown) on the margins but a broad light area covers the middle; as a result the under side of the arm appears to be brown (basally) or green, with a broad longitudinal light stripe along the middle. This type of coloration is frequent in specimens from the Galápagos Islands.

Geographical Distribution: Lower California to Panama; also Cocos and Galápagos Islands; low water to 10 fms.

***Ophiopteris papillosa* (Lyman).**

Ophiocoma papillosa Lyman, 1875. *Illus. Cat. M.C.Z.*, No. 8, pt. 2, p. 11.

Ophiopteris papillosa McClendon, 1909. *Univ. Cal. Publ. Zool.*, 6, p. 49.

A young individual, scarcely 5 mm. across the disk and light grayish-brown in color, was collected at St. 126, D 19, in 25 fms., southeast of Cedros Island, Lower California.

Geographical Distribution: Carmel Peninsula, California, to Todos Santos Bay, L.C., Mexico; low water to 50 fms.

***Ophioderma panamense* Lütken.**

Lütken, 1859. *Add. ad Hist. Oph.*, pt. 2, p. 91.

There are 12 specimens of this common brittle-star, ranging from 9 to

19 mm. across the disk. They show some diversity in color from gray and brown to more or less olive-green; the arms are banded in all at least distally, and this is the best distinction from *teres*. They were taken at St. 195 (Port Guatulco, Mexico), at Cardon Island, Corinto Bay, Nicaragua, and at Port Parker, Ballenas Bay and Uvita Bay, Costa Rica, always in very shallow water. Two specimens were taken in *Pocillopora* coral, Jasper Island, Gulf of Nicoya, Costa Rica, 1 fm.

Geographical Distribution: San Pedro, California, to Payta, Peru; also Cocos and Galápagos Islands; low water to 10 fms.

***Ophioderma teres* (Lyman).**

Ophiura teres Lyman, 1860. *Proc. Boston Soc. Nat. Hist.*, 7, p. 198.

Ophioderma teres Meissner, 1901. *Bronn's Thier-reichs*, 2, pt. 3, p. 915.

The examination of the *Ophiodermas* brought back by the *Zaca* revealed the interesting fact that the 8 specimens to be referred to *teres* fall into two easily distinguished groups. One of these is made up of unicolored individuals, usually very dark. The other consists of individuals having the dull purplish upper arm-plates more or less conspicuously spotted with light buff or cream-color; the disk is also more or less conspicuously spotted with the same light shade. Moreover the lower surface of the arms, including the lowest arm-spines, is white or pale yellowish, in marked contrast to the dull interbrachial areas and sides of the arms. A re-examination of Lyman's original description shows that his type of *teres* was one of these spotted individuals, which are strikingly different from *panamense*. Unfortunately however the unicolored specimens are not so easily distinguished but seem to intergrade with *panamense*. Nielsen (1932) suggested as the best distinction between them that in adult *teres* many upper arm-plates (usually all or nearly all) are broken into two or more irregular fragments. This fragmentation may occur in *panamense* but only in a few plates. Unfortunately it is often insignificant in young *teres*. Usually *panamense* is grayish or greenish or brown with more or less conspicuously banded arms. It is never speckled as is typical *teres*, which also lacks any bands on the arms. The unspeckled form of *teres*, which apparently seldom occurs with the typical form, is often very dark brown and the lower surface of the arms (except maybe near the disk) is not notably lighter. The arms are however rarely banded distally and then only in small specimens; of course such specimens are hard to tell from *panamense* but in *teres* the light band consists of a short longitudinal white streak on each side of 3 or 4 segments separated by a narrow dark line. In *panamense* the light bands are more diffuse and variegated. On the whole the atypical form of *teres* needs a distinctive name and may well be called variety *unicolor*. A specimen from the Galápagos Islands, 35 mm. across the disk, M.C.Z. No. 114, may be designated as the type. A very similar specimen, 31 mm. across the disk, is in the present collection from Cardon Island, Corinto, Nicaragua, accompanied by 2 smaller specimens, one only 10 mm. across the disk.

The specimens of typical *teres* in the *Zaca* collection are from the Arriba Isthmus and Abajo Isthmus, Port Parker, Costa Rica. The largest is 32 mm. across the disk. A small specimen was taken in *Pocillopora* coral from Jasper Island, Gulf of Nicoya, Costa Rica, 1 fm.

Geographical Distribution: Gulf of California to Panama; also Galápagos Islands; low water to 10 fms.

***Ophioderma variegatum* Lütken.**

Lütken, 1856. *Vid. Med.*, p. 21.

This slender-armed and often brightly colored species is easily recognized by the naked adoral plates yet it is often confused with *panamense*. There are 5 specimens at hand, not notable in any way. They are all dull grayish-green above with banded arms and the oral area nearly or quite white; the under surface of the arms is also nearly white in the largest specimen, which is 13 mm. across the disk. In 2 of the specimens, a conspicuous light gray area covers more or less of the disk. This quintet were taken at St. 200, Corinto, Nicaragua, on mangrove leaves, in 2-3 fms.

Notably different are 10 specimens from St. 195 D-17, -18, Port Guatulco, Mexico, on sand in 6 fms. These are white beneath and strikingly variegated above with green, rose-red and cream-color, and light and dark dusky shades. There are 7 similar specimens from St. 196, Tangola-Tangola Bay, Mexico, 7-10 fms., and a single large individual, 15 mm. across the disk, from St. 182 D-4, Chamela Bay, Mexico, in 16 fms. on sand. There are also 2 small specimens from St. 213 D-6, -7, -8, -9, off Cedro Island, Costa Rica, 4-6 fms.

Geographical Distribution: San Diego, California, to Panama; also Cocos Island; low water to 60 fms.

***Diopederma danianum* (Verrill).**

Ophiura danianum Verrill, 1867. *Trans. Conn. Acad.*, 1, p. 254.

Diopederma danianum H. L. Clark, 1913. *Bull. Amer. Mus. Nat. Hist.*, 32, p. 206.

This characteristic brittle-star of the western coast of Central America is represented by 30 specimens, ranging from 9 to 26 mm. in disk diameter. They were taken at the following stations: St. 183 D-2, Tenacatita Bay, Mexico, 30 fms.; St. 195 D-20, -21, Port Guatulco, Santa Cruz Bay, Mexico, 18-23 fms.; St. 196 D-6, Tangola-Tangola Bay, Mexico, 7 fms.; St. 197 D-2, 7 miles west of Champerico, Guatemala, 14 fms.; St. 198 D-1, -2, La Libertad, El Salvador, 13-14 fms.; St. 199 D-1, Gulf of Fonseca, El Salvador, 16 fms.

Geographical Distribution: Lower California and Cocos Island to Panama; 3-25 fms.

***Schizoderma diplax* Nielsen.**

Nielsen, 1932. *Vid. Med.*, 91, p. 335.

This remarkable ophiuran was taken by the *Zaca* in 1938, only at St. 214 D-1, -2, -3, -4, 14 miles southeast of Judas Point, Costa Rica, on a bottom of mud and shell in 42 fms. There are 19 specimens ranging from 6 to 11 mm. in disk diameter.

Geographical Distribution: Lower California to Panama; low water to 60 fms.

***Ophiura lütkenii* (Lyman).**

Ophioglypha lütkenii Lyman, 1860. *Proc. Boston Soc. Nat. Hist.*, 7, p. 197.

Ophiura lütkeni Meissner, 1901. *Bronn's Thier-reichs*, 2, pt. 3, p. 925.

This northern brittle-star was found at St. 126 D-13, in 45 fms., east

of Cedros Island, Lower California, the southern limit of its range so far as yet known. The 8 specimens are all small, only about 8 mm. across the disk.

Geographical Distribution: Alaska to Lower California; 15-100 fms.

***Ophiozona pacifica* (Lütken).**

Ophiolepis pacifica Lütken, 1856. *Vid. Med.*, p. 22.

Ophiozona pacifica Lyman, 1865. *Illus. Cat. M.C.Z.*, 1, p. 64.

There are 2 small adults of this species in the collection, both taken in *Pocillopora* coral from Jasper Island, Gulf of Nicoya, Costa Rica, 1 fm.

Geographical Distribution: Previously known only from the Gulf of Panama; low water to 10 fms.

Genus *Ophiolepis*.

This genus is represented by 318 specimens ranging from 1½ to 24 mm. in disk diameter. As none of them can be properly referred to either *crassa* or *plateia*, it would be natural to refer them to the third West Coast species, the long-known *variegata*. But even a superficial examination shows this to be an utterly erroneous procedure. Yet patient and long-continued study has failed to discover a natural or satisfactory grouping. Aside from those more or less adult specimens which are unquestionably *variegata*, there are two groups, very unlike each other, which are so different from *variegata*, it seems most natural to consider them distinct species. Unfortunately this does not clear up the matter, as there are still many specimens, 9 mm. or less in disk diameter, which cannot be referred definitely to any one of the 3 species. These specimens seem to be young *variegata* but most of them are so unlike small specimens which are undoubtedly that species that one cannot be wholly satisfied to call them *variegata*. It seems best to include them for the present under that species, to which attention may now be given.

***Ophiolepis variegata* Lütken.**

Lütken, 1856. *Vid. Med.* p. 23.

From St. 182 D-4, in Chamela Bay, Mexico, 16 fms., there are 7 very good typical examples of this handsome species, 10-17 mm. across the disk; the arms are 3 times the disk diameter. There are usually 3 arm-spines, the lowest the smallest and the uppermost largest, but at the base of the arm in the larger specimens there may be 4 spines and if so the uppermost may be the smallest; the spines are usually quite sharply pointed but in the larger specimens they may be thick clear to the tip and with a rather blunt point.

From St. 184 D-2, at Manzanillo, Mexico, 30 fms., and from St. 195 D-17-20, in Port Guatulco, Mexico, 6-23 fms., there are 38 specimens, 7-15 mm. across the disk, very similar in all respects to those from St. 182, but in the smallest there are but 2 arm-spines on most of the arm-segments near the middle of the arm, the upper one the larger, while basally and distally there are 3 as usual. From this same station, 195 D 17-20, there are 69 specimens, which I cannot determine satisfactorily but which I am for the present considering young *variegata*. They differ obviously from typical young individuals of the same size, in that the disk is very flat and thin and nearly or quite circular, instead of being higher than the arm-bases and definitely pentagonal. The arm-spines are usually 2 but on some part of the arm, *often far distal*, there are 3 as in typical *variegata*. Orally there are no tangible, constant differences. In color, the small flat individuals are much more variegated than typical *variegata*, the disk and arm-plates them-

selves being blotched, mottled or speckled in marked contrast to the solidly colored plates and scales of the typical form. The banding of the arms may be almost entirely wanting or, at best, quite indistinct in these odd, youthful, individuals, which are 6.5-9 mm. across the disk.

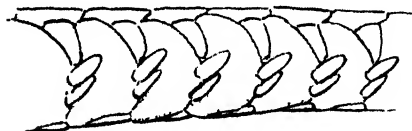
From St. 196 D-6, 13-15, in Tangola-Tangola Bay, Mexico, 5-10 fms., there are 8 specimens which are clearly *variegata*. The smallest is only 3 mm. across the disk and has only 2 arm-spines on each side arm-plate, but the scaling of the disk and its coloring are quite typical. In 3 individuals 5-7 mm. across, the disk is very similar but there are 3 arm-spines on many segments. The remaining 4 specimens are 12-16 mm. across the disk and often have 4 arm-spines basally. From this same station there are 21 small individuals, 4-10 mm. across the disk, which are like the perplexing lot described above from St. 195. Although they are here included under *variegata*, I am not satisfied with that identification.

Geographical Distribution: Gulf of California to Gorgona Island, Colombia; low water to 60 fms.

***Ophiolepis fulva*³ sp. nov.**

Text-figure 3.

Disk 8 mm. in diameter, arms 21-23 mm. long. Disk flat, thin, rounded pentagonal or quite circular, covered as in *variegata* by relatively large plates, encircled by small ones; a notable peculiarity is that the central group of 6 plates (a central surrounded by 5 radials) is rarely symmetrical and never conspicuous; in many specimens it is quite indistinguishable. The arms are somewhat widened at the base but not much flattened; the upper arm plates are rounded hexagonal and, excepting the first 2 or 3, are as long as wide or longer, with nearly straight distal margin; the supplementary plates are relatively conspicuous. The side arm-plates are very large, longer than high, the distal margin not symmetrically semi-circular in outline but the lower half somewhat projecting and carrying 2 short, blunt,



Text-figure 3.

Ophiolepis fulva. Six arm segments, seen from the side. $\times 14$.

thick arm-spines, the upper one often the larger and longer. The under arm-plates are longer than wide, except the first half dozen, and the distal margin is definitely convex. Otherwise the oral surface is not evidently different from that of *variegata*, although the arms at disk margin are definitely less widened.

The color of the dorsal side is a mixture of browns and lighter shades, inextricably mingled. The general impression is fulvous. The arms are cross-banded on the upper surface, but there is no little diversity in the number, width and distinctness of the bands. There is no indication of red. The lower surface is tinted with yellow. Of course, the generally yellow-tinted color is not the most important specific character but it is quite obvious and as a rule is the most conspicuous feature. The side arm-plates and arm-spines are distinctive and the irregular plating of the disk and the narrow arm-bases are helpful characters.

Holotype, M.C.Z. No. 6049, from Zaca St. 195 D-13.

There are 152 paratypes, ranging from 1.5 to 8 mm. in diameter of disk. All the material is from St. 195 D-13, Port Guatulco, Mexico, 8 fms., sandy

³ *fulvus*—brownish-yellow, tawny, in reference to the coloration.

bottom. There is great diversity in the relative quantity of light and dark browns, whites and creamy tints, some specimens being brighter or duller than the holotype, but the generally fulvous tint is notably different from the redder or grayer tints of other species.

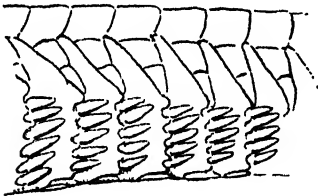
Geographical Distribution: Known only from the Zaca 1937-38 collecting.

***Ophiolepis grisea*⁴ sp. nov.**

Text-figure 4.

Disk flat, pentagonal, 22 mm. in diameter. Arms 5, rather more than 100 mm. long or nearly 5 times the disk-diameter. In young individuals, 8-10 mm. across the disk, the arms are a trifle more than 4 times disk diameter.

The primary plates of the disk are very evident particularly in the smaller specimens. The central plate is usually noticeably smaller than the encircling ring of 5 radials. The arms are wide at the disk margin (6 mm. in holotype) but are well arched and not at all flattened basally. Upper arm-plates wider than long even far out on the arm; near the disk they are very short, 3-4 times as wide as long; supplementary plates, at least 2 on each side, extending far down on the sides of the arm. Side arm-plates high and short, carrying 4 or often 5, and sometimes, close to disk, 6 spines. These spines are relatively very small, flattened and sharp pointed; when 5 or 6 are present, the lowest and uppermost are smallest, the third from the bottom the longest; when 4 only are present, the lowest is smallest while the other 3 may be subequal, or the uppermost smallest. The longest scarcely exceeds one-half the side arm-plate. In the young specimens from St. 213,



Text-figure 4.

Ophiolepis grisea. Six arm segments, seen from the side. $\times 7$.

the arm-spines on the basal part of the arms are bristling, standing out at right angles from the arm, but in adults, all the spines are closely appressed to the side of the arms. Oral surface, even including the under arm-plates, much as in *variegata*. Color definitely gray, more or less marked on both disk and arms with lighter areas and with white spots or speckles. Under the lens, there are many blackish spots and markings evident on both disk and arms. Lower surface uniformly buffy white—not so near a real white as in *variegata*. The line of demarcation between the upper and lower surfaces is very sharply drawn on the sides of the arms, just above the uppermost arm-spine. The arm-spines are therefore all white. The arms are not really banded but at rather definite intervals there are transversely placed, somewhat elliptical areas, which distally become narrow light bands. Between these areas there are widely separated small white spots, 4-7 on each arm. In young individuals (less than 10 mm. across the disk) the banding of the arms is more definite and in most such specimens there is a large irregular light blotch on the disk, although this may be broken up into several small spots.

Holotype, M.C.Z. No. 6050, from Zaca St. 199 D-5.

There are 4 paratypes from the same station, 199 D-5, which is off Monypenny Point, Gulf of Fonseca, 7 fms., on a muddy bottom. These range from 16 to 24 mm. across the disk but call for no comment. From St. 199

⁴ *griseus* = gray, in reference to the prevailing color.

D-7, there are 3 specimens, each of which deserves mention. This station, while in the Gulf of Fonseca, was in 6 fms. off La Union, El Salvador, and the bottom is described as "mud, mangrove leaves." The smallest specimen is 18 mm. across a square disk as it is symmetrically tetramerous. Its color is like those from off Monypenny Point but the buffy shade of the lower surface is deeper. A second specimen, 22 mm. across, has a similar pale buff lower surface but the upper side is a light sandy gray; the blotches and marks and arm-bands are as in the darker gray individuals. The third specimen, 23 mm. across, also has the pale buff lower surface, but the upper side has a definitely reddish cast, which makes the lighter gray blotches and arm-bands stand out more sharply than in any other specimen. One can but wonder whether the mangrove leaves in the mud were a factor in causing the brighter coloration.

From St. 213 D-6-9, off Cedro Island, Gulf of Nicoya, Costa Rica, 4-6 fms., mud, sand and shell, there are 15 specimens of *Ophiolepis*, 6-13 mm. across the disk, which are apparently the young of this fine species. The gray coloration with white or light gray markings on the disk and in narrow bands on the arms is like that of the adults and even in the smallest individual there are 4 arm-spines on some at least of the basal arm-segments, while in *variegata* of such a size there are usually but 2. The arms are noticeably slender and arched. The bristling arm-spines on the basal half of the arm are probably a result of sudden immersion in alcohol, and not a normal condition.

This large and handsome species was at first regarded as a form of *variegata* but the character and arrangement of the arm-spines, the coloration, and the longer arms preclude such a decision. The color suggests *plateia* Ziesenhenné but the length and character of the arms set it off very decidedly from that species. There seems to be no doubt therefore that it must be recognized as a distinct species.

Geographical Distribution: Known only from the *Zaca* 1937-38 collecting.

ECHINOIDEA.

Eucidaris thouarsii (Agassiz & Desor).

Cidaridaris thouarsii Agassiz & Desor, 1846. *Ann. Sci. Nat.* (3), 6, p. 326.

Eucidaris thouarsii Döderlein, 1887. *Jap. Seeigel*, p. 42.

There are 10 specimens of this common urchin but only 2 are adult and none is full grown. They were collected at the following places:

Mexico, Manzanillo, 30 fms., 2 young.

Mexico, Sihuatanejo, 2 adults and 2 young.

Panama, Bahia Honda, 30-50 fms., 3 young.

Geographical Distribution: Lower California to Panama; also Cocos and Galápagos Islands; low water to 50 fms.

Stylocidaridaris dubia (H.L. Clark).

Tretocidaridaris dubia H.L. Clark, 1907. *Bull. M.C.Z.*, 51, p. 204.

Stylocidaridaris dubia Mortensen, 1909. *Ech. Deutsche Südp. Exp.*, p. 52.

There are 4 very fine adults of this rather uncommon cidarid, 35-40 mm. in test diameter, from St. 214 D-4, 14 miles south by east off Judas Point, Costa Rica, in 61 fms., and 41 young individuals, 5-25 mm. through the test, from St. 224 D-1-3, on Hannibal Bank, Panama, in 35-40 fms.

Geographical Distribution: Gulf of Panama to Gorgona Island, Colombia; 15-112 fms.

***Astropyga pulvinata* (Lamarck).**

Cidarites pulvinata Lamarck, 1816. *Anim. s. Vert.*, 3, p. 59.

Astropyga pulvinata Agassiz & Desor, 1846. *Ann. Sci. Nat.* (3), 6, p. 345.

There are 3 notable specimens of this very handsome sea-urchin. One from St. 232, off Gorgona Island, Colombia, 2-8 fms., sand, is probably the smallest specimen yet recorded; it is scarcely 4 mm. in diameter, with bright red interambulacra, brown-violet ambulacra, and white oral surface; the slender, fragile spines are 5 mm. long, pale yellowish-green banded with brown-violet. The other specimens are adult and were taken at St. 195 D-2, in Port Guatulco, Mexico, in 3 fms. on sand; the smaller is 85 mm. across, brown-violet above except for sharply defined, triangular areas on the distal portion of each intrambulacrum, which are light reddish-brown, and fade out into the very pale brown of the oral surface; the spines are pale green on the aboral side of the test, more nearly white orally, but prettily marked with numerous narrow rings (6-12) of dull violet. The larger specimen is 110 mm. across with the test colored much as in the smaller but the spines show little banding except at the very base of a few; orally they are nearly white but at the ambitus they become dull violet basally and dorsally most of the spines are violet, although some are white at the tip. Evidently the green tint which is so conspicuous on the spines of the young individuals tends to disappear with age.

Geographical Distribution: Gulf of California to Panama; low water to 36 fms.

***Arbacia incisa* (A. Agassiz).**

Echinocidaris incisa A. Agassiz, 1863. *Bull. M.C.Z.*, 1, p. 20.

Arbacia incisa H.L. Clark, 1913. *Bull. Amer. Mus. Nat. Hist.*, 32, p. 220.

There are 5 small specimens from St. 126 D-18, -19, southeast of Cedros Island, Lower California, 20-25 fms., notable only for their uniformly blackish color. They range from 6 to 23 mm. in test diameter.

Geographical Distribution: Lower California to Zorritos, Peru; also Galápagos Islands; low water to 29 fms.

***Lytechinus anamesus* H.L. Clark.**

H.L. Clark, 1912. *Mem. M.C.Z.*, 34, no. 4, p. 254.

A single small specimen, 18 mm. in diameter, taken at St. 126 D-13, off Cedros Island, Lower California, in 45 fms., is the only representative of this species, so characteristic of southern California.

Geographical Distribution: Santa Barbara, California, to Point San Bartolome Bay, Lower California, 30-60 fms.

***Lytechinus pictus* (Verrill).**

Psammechinus pictus Verrill, 1867. *Trans. Conn. Acad.*, 1, p. 301.

Lytechinus pictus H.L. Clark, 1912. *Mem. M.C.Z.*, 34, no. 4, p. 258.

This is another sea-urchin characteristic of southern California and the west coast of Mexico. It is represented in the *Zaca* collection by 10 very young specimens, 3.5-13 mm. in diameter, taken at St. 126 D-18 off Cedros Island, Lower California, in 20 fms. The relationship between *pictus* and *anamesus* is very close and it is not unlikely that the latter is only a

long-spined form of *pictus* characteristic of deeper water, for it ranges from 20 down to 113 fms. while *pictus* is characteristic of the more strictly littoral zone.

Geographical Distribution: Monterey, California, to Gulf of California; also Cocos Island; low water to 50 fms.

***Toxopneustes roseus* (A. Agassiz).**

Boletia rosea A. Agassiz, 1863. *Bull. M.C.Z.* 1, p. 24.

Toxopneustes roseus Mortensen, 1903. "Ingolf" *Ech.*, pt. 1, p. 136.

This large sea-urchin characteristic of the littoral zone of western Central America is represented by 3 specimens 65 to 80 mm. in diameter. The label says they were "flesh-colored" in life. They were taken at St. 222 D-3, in Bahia Honda, Panama, in 8 fms.

Geographical Distribution: Mazatlan, Mexico, to Port Utria, Colombia; low water to 30 fms.

***Strongylocentrotus purpuratus* (Stimpson).**

Echinus purpuratus Stimpson, 1857. *Crust. Ech. Pac. Shores N. Amer.*, p. 86.

Strongylocentrotus purpuratus A. Agassiz, 1872. *Rev. Ech.*, pt. 1, p. 165.

A specimen 45 mm. in diameter is undoubtedly a representative of this northern species. It was taken at Guadeloupe Island, off Lower California, Nov. 8, 1937, but the *Albatross* took *purpuratus* in 1911 near Cedros Island, which is somewhat further south.

Geographical Distribution: Puget Sound to Lower California; low water to 10 fms.

***Echinometra vanbrunti* A. Agassiz.**

A. Agassiz, 1863. *Bull. M.C.Z.*, 1, p. 21.

This well known Mexican sea-urchin was taken at the following places: Mexico: Sihuatanejo Bay, 1 very small specimen, 9 mm. long.

Nicaragua: Corinto, Cardon Island, tide pools, 2 small adults.

Costa Rica: Uvita Bay, under rocks on reef, 1 small adult.

Geographical Distribution: Lower California to San Francisco Bay, Ecuador; also Cocos and Galápagos Islands; low water to 10 fms.

***Clypeaster europacificus* H.L. Clark.**

H.L. Clark, 1914. *Mem. M.C.Z.*, 46, p. 27.

There are 5 representatives of this fine clypeastroid in the collection. Two large adults, 150 mm. long, yellow-green in color, and two young ones, 50 and 54 mm. long, dull purple above but nearly white underneath, were taken at St. 214 D-1, 14 miles south by east of Judas Point, Costa Rica, in 42-61 fms. on a muddy bottom. The fifth specimen is a very young one, only 14 × 13 mm.; the upper surface is light dull purple, with pale greenish spines, while the oral side is light greenish-yellow, almost white. It was taken at St. 224 D-1, -2, -3, on Hannibal Bank, 35-40 fms.

Geographical Distribution: Gulf of California to Panama; also Galápagos Islands; 7-56 fms.

***Clypeaster ochrus* H.L. Clark.**

H. L. Clark, 1914. *Mem. M.C.Z.*, 46, p. 30.

There are 2 *Clypeasters* from St. 195 D-9, Port Guatulco, Mexico, 7 fms., green sand and shell, which are typical *ochrus* in form and tuberculation of the test, but differ so markedly in color that I have hesitated over calling them by that name. The test is reddish-white, most nearly white on the dorsal interambulacral areas, most nearly dull rose-red on the poriferous areas of the petals and on the oral surface. The spines are dirty white or pale greenish but often have a rosy-tinge and the terminal portion may be quite roseate or even dull-red. The smaller specimen, $59 \times 55 \times 15$ mm., is more roseate than the larger, $80 \times 73 \times 20$ mm. If this coloration is natural, and there is not the slightest reason for thinking it artificial, and should prove to be constant in any considerable group or area, it would warrant a varietal name because it is so conspicuously different from the usual color.

Geographical Distribution: Isabel Island, Mexico, to Port Utria, Colombia; low water to 30 fms.

***Clypeaster speciosus* Verrill.**

Verrill, 1870. *Amer. Jour. Sci.* (2) 49, p. 95.

There are 2 small *Clypeasters* from St. 184 D-2, off Manzanillo, Mexico, 30 fms., which are best referred to this species. They are obviously young but in the form of the test and the character of the petals seem to be *speciosus*. The larger is $65 \times 55 \times 17$ mm., the smaller $44 \times 39 \times 11$. They are yellow-brown in color, more brown above, quite yellow orally, especially the smaller one. The oral surface is rather flat but is distinctly depressed about the mouth. The petals are relatively narrow but well opened at the tip. The periproct is strictly marginal in both specimens but I have never seen any other case in *speciosus* although I have examined a number of specimens of which several were younger than these. Because of this position of the periproct and the light yellow-brown color, I have hesitated to call these young *Clypeaster speciosus* but I hesitate even more to consider them a "new" species.

Geographical Distribution: Lower California, also Cocos and Galápagos Islands; low water to 50 fms.

***Moira clotho* (Michelin).**

Moera clotho Michelin, 1855. *Rev. Mag. Zool.*, p. 247.

Moira clotho A. Agassiz, 1872. *Rev. Ech.*, pt. 1, p. 147.

A superb series of this apparently rare spatangoid was taken at St. 213 D-2, off Cedro Island, Gulf of Nicoya, Costa Rica, in 4 fms. on a muddy bottom. There are 11 specimens ranging from 9 mm. $\times 8 \times 6$ to a very fine adult, $50 \times 45 \times 37$. The two smallest specimens are more or less badly damaged but the others are in beautiful condition. All are pale fawn color, the fascioles and petals somewhat darker, the enlarged tips of the spines on the plastron, pure white.

Geographical Distribution: Lower California to Panama; low water to 10 fms.

***Plagiobrissus pacificus*⁵ sp. nov.**

Plate II; figs. 3 & 4.

Test elongated and flattened, 36 mm. long, 25 mm. wide and 11-12 mm. high. So similar to *P. grandis* of the West Indian region that it is difficult to feel sure what characters are specific and what are merely due to youthfulness. The smallest specimen available of *grandis* is nearly twice as large, $63 \times 45 \times 23$ mm. The Pacific species seems to be flatter and more rounded anteriorly, but the only character shown which would seem to be surely specific is in the ventral ambulacra. In the West Indian species these ambulacra, on each side of the ventral plastron are extraordinarily narrow and the plastron, like the lateral interambulacra, is densely covered with tubercles; this is as true for the smallest as for the largest specimens. In the specimen from the Pacific, these ambulacra are comparatively wide and the plastron itself is narrower and less well-defined. This difference is best shown by the actual measurements. In the smallest *grandis*, measured across the middle of the ventral surface, we find the plastron is 14 mm. across, the bare ambulacra on each side, only 3 mm., and the lateral interambulacra (to test margin) 12.5 mm. In the type of *pacificus* the same measurements are 5, 3 and 7 mm. Thus in *pacificus*, the plastron is not equal in width to the two ambulacra while in *grandis* it is more than double their combined width; in *pacificus*, the ambulacra are almost half as wide as the lateral tuberculated areas but in *grandis* they are scarcely one-fourth as much. As a result of these differences the lower surface of *pacificus* looks quite unlike that of *grandis*. One can only speculate as to how much of this difference would persist in a *pacificus* 100 mm. long. The spines and pedicellariae in the two species are similar but only a few pedicellariae are to be seen in the specimen from the Pacific. One large tridentate with very narrow, widely divergent valves was found and 2 or 3 of the "long globiferous" can be seen near the posterior end of ambulacrum 5. A few very minute ophicephalous pedicellariae are to be seen among the ventral spines. The peristome in *pacificus* is relatively long and little depressed and the plates covering it are notably longer than wide; but these are very likely youthful rather than specific characters. The color of the specimen is very pale fawn, nearly white—the test dorsally is white.

Holotype, M.C.Z. No. 7625, from St. 224 D-1,-2,-3, on Hannibal Bank, Panama, in 35 fms.; in view of the character of the specimen and the known habits of the West Indian species, it is pretty certain that *pacificus* was secured in the third haul of the dredge, which was on a bottom of sand, shells and algae.

Besides the holotype, a second specimen was secured at the same time, but is so much younger, it is of no help in defining the species. It measures $19 \times 14.5 \times 6.5$ mm. and shows the same wide ventral ambulacra as the holotype but even less well defined and more obviously youthful.

The discovery of this genus on the western coast of Central America is of the greatest interest. It furnishes another link connecting the Panamic with the West Indian fauna and is particularly interesting in showing that striking novelties are still to be found in the Panamic region in spite of the large amount of collecting and dredging that have been done there in the past forty years.

Geographical Distribution: Known only from the Zaca collection.

⁵ *pacificus*, in reference to the habitat, all other members of the genus occurring in the Atlantic region or Mediterranean.

***Meoma grandis* Gray.**

Gray, 1851. *Ann. Mag. Nat. Hist.* (2), 7, p. 132.

A single specimen of this spatangoid was taken at St. 195 D-16, in Port Guatulco, Mexico, 10 fms., sand. It measures $98 \times 85 \times 48$ mm. and the color is a real brown.

Geographical Distribution: Gulf of California and west coast of Mexico, 20-60 fms.

***Lovenia cordiformis* A. Agassiz.**

A. Agassiz, 1872. *Bull. M.C.Z.*, 3, p. 57.

A small specimen, $35 \times 28 \times 14$ mm., of this typically southern Californian spatangoid, was taken at St. 126 D-19, southeast of Cedros Island, Lower California, in 25 fms. The color is definitely light brown.

Geographical Distribution: Santa Barbara, California, to Guayaquil, Ecuador; also Cocos, Galápagos and Hawaiian Islands.

EXPLANATION OF THE PLATES.**PLATE I.**

Fig. 1. *Othilia aculeata* Gray. Aboral surface. $\times 1.5$.

Fig. 2. Oral surface. > 1.5 .

PLATE II.

Fig. 3. *Plagiobrissus pacificus* sp. nov. Aboral surface. $\times 2$.

Fig. 4. Oral surface. $\times 2$.

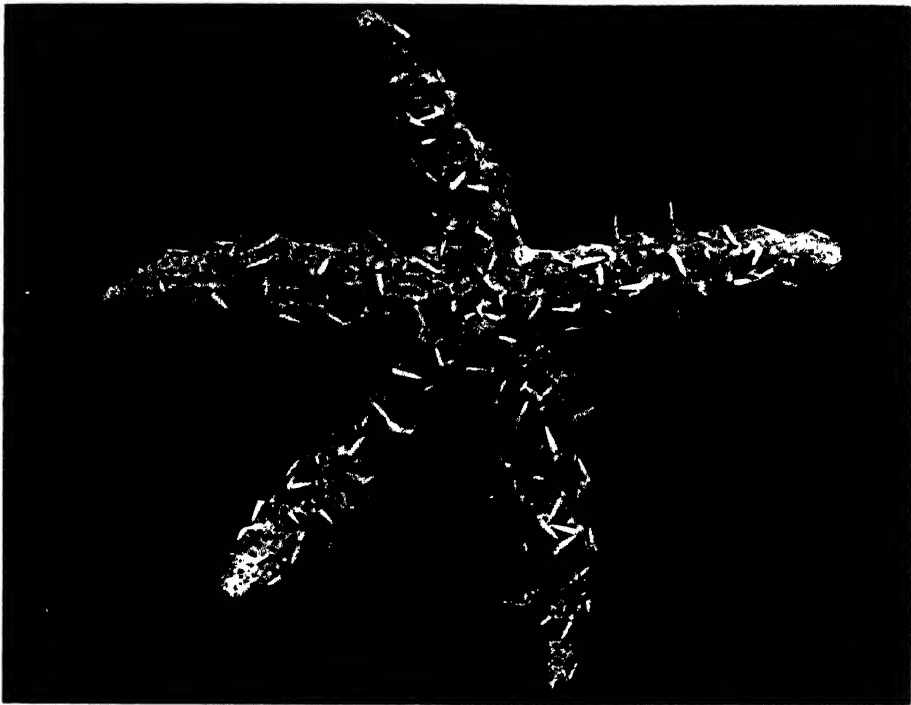


FIG. 1

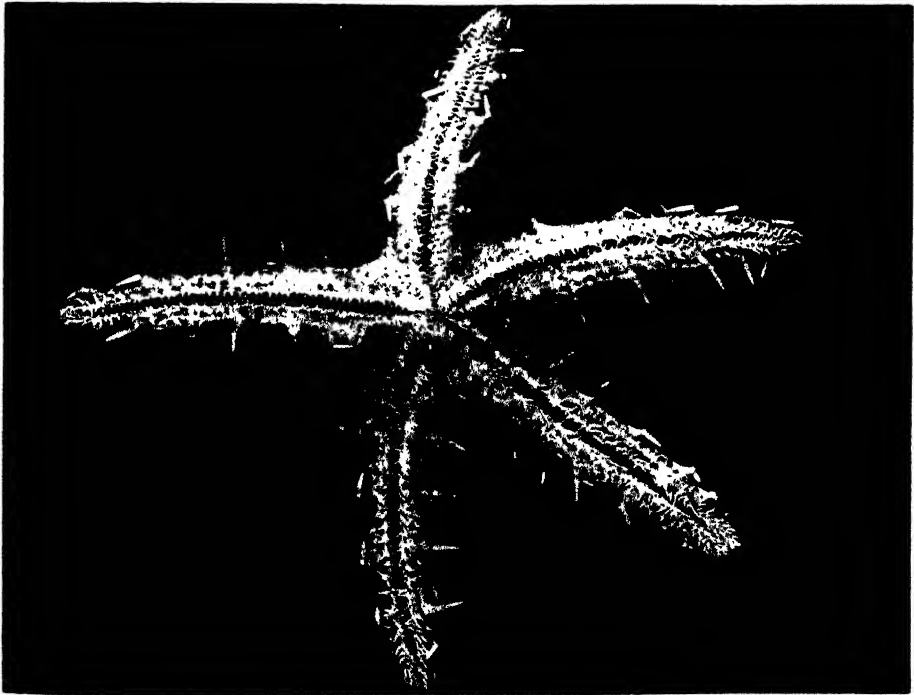


FIG. 2.

NOTES ON ECHINODERMS FROM THE WEST COAST OF CENTRAL AMERICA.

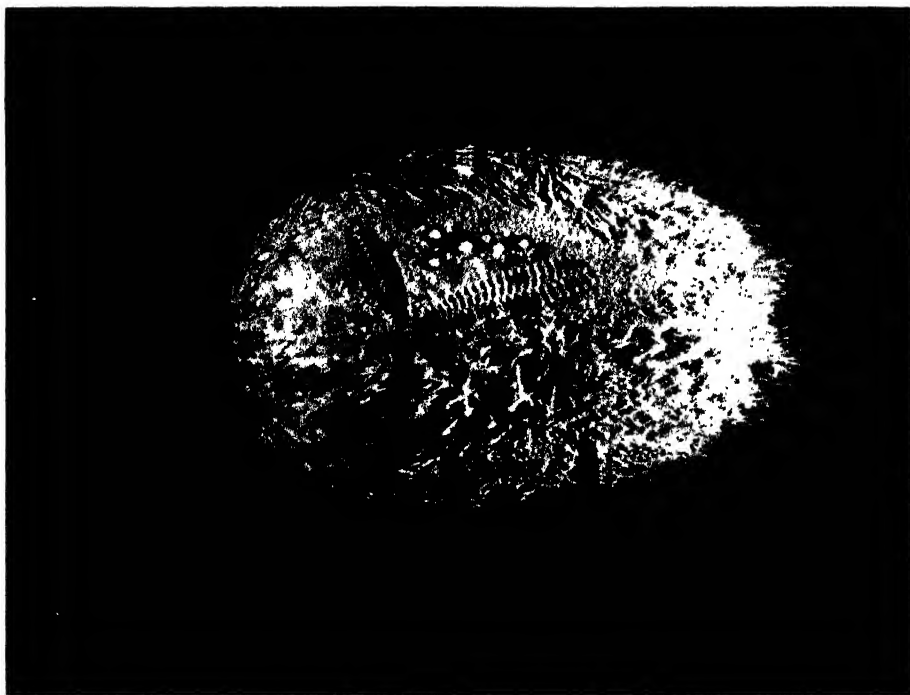


FIG. 3

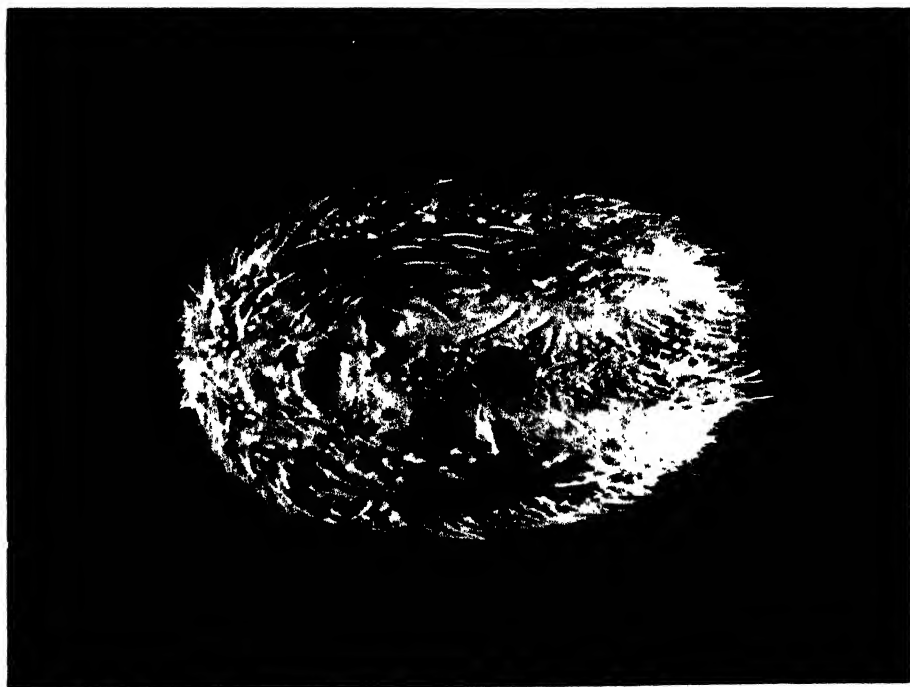


FIG. 4.

NOTES ON ECHINODERMS FROM THE WEST COAST OF CENTRAL AMERICA.

23.

The Nesting Behavior of *Eupomotis gibbosus* (Linnaeus)
In a Small Pool.

C. M. BREDER, JR.

New York Aquarium

(Plates I & II; Text-figures 1 & 2).

INTRODUCTION.

A general study of the nesting behavior of the family Centrarchidae has already been given in this journal (Breder, 1936). The present contribution is based on a continuation of these studies on one species, *Eupomotis gibbosus* (Linnaeus), and compared with other studies on a very different type of fish, *Ameiurus nebulosus* (Le Sueur), under an identical situation (Breder, 1939).

In the spring of 1940 fourteen mature *Eupomotis* were placed in a pool on the writer's property. This pool has been described in detail by Breder (1939), and its general form may be seen in Text-fig. 1. Due to an unusually hard freeze the *Ameiurus* which occupied it the previous year were all frozen out, although the *Rhodeus amarus* which shared the pool with them survived. Thus the pool, in addition to being physically similar, was also alike in the organisms present in addition to those under study.

The *Eupomotis* were collected from the lake in Central Park, New York City, at 59th Street, as part of a considerable number taken to the New York Aquarium. These fish were in their second year and were 10 cm. long. The chief purpose of the experiment was to note the number of nests constructed in a given body of water by a known number of fish and to compare their behavior with that of the previously studied *Ameiurus*. It was impossible to determine the numbers of each sex with certainty or to keep track of each individual fish under the conditions of the experiment.

REPRODUCTIVE SCHEDULE.

Pre-spawning Behavior.

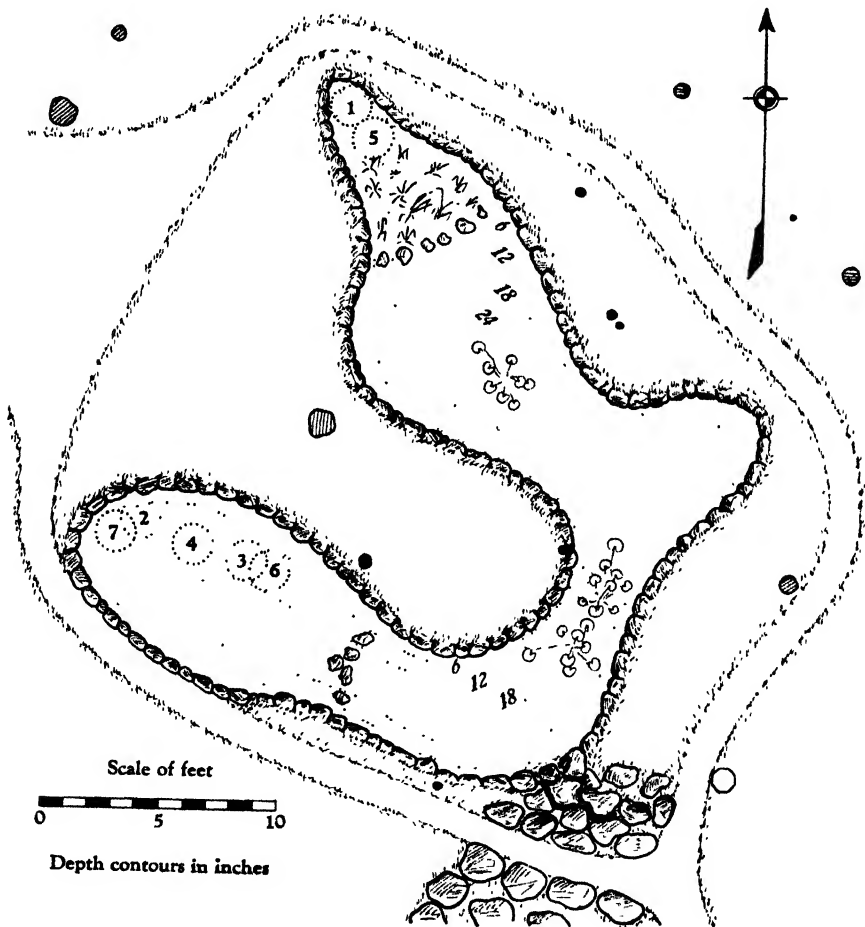
The fish were released on May 5 when the water was about 18.5° C. As they began nesting on May 18, by which time it had reached 20°, there was not much time for observation of the pre-spawning behavior. After a few days of accommodation and exploration, the fish settled in a school in or over the deepest part of the pool, near the water lilies in the north arm, rising to near the surface on sunny days and staying in the deeper parts at night and on dark days. Here they remained for the most part, with occasional short sallies to other places until nest construction began. Those fish not engaged in this activity continued to behave in a similar manner except that as the season advanced they moved from the northwest part of the 24"

contour to the southeast. Much later a group of four or five was frequently seen in the southwest extension of the 18" contour which reaches into the southwest arm of the pool.

Nest Construction.

In all, seven nests were excavated, and since there were fourteen fish it is tempting to assume that the sexes were equally divided and that each male built one nest. It is doubtful if such is actually the case, however, as there is reason to believe that some of the males built more than one nest, as will be shown subsequently.

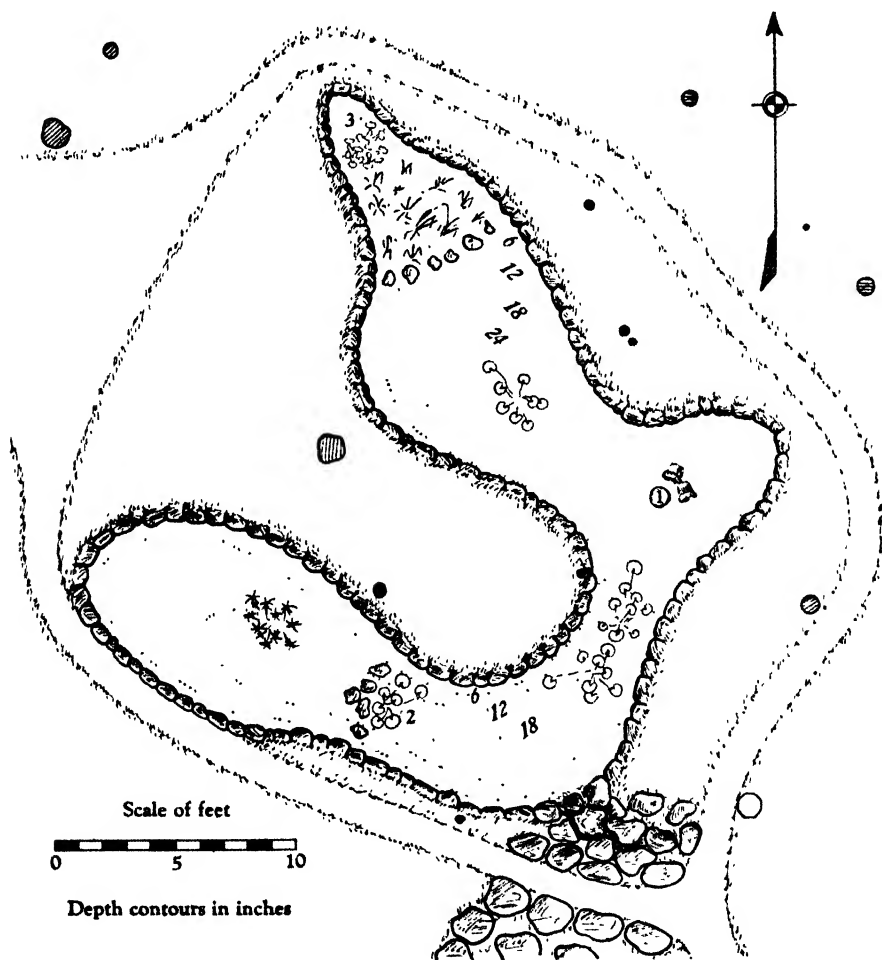
The nests are numbered in Text-figure 1 in the order of their construction, which gives a measure of order of choice of locality. Considered this way, there were actually only three major choices, since nest 6 and nest 7



Text-figure 1.

Sketch map of the pool in which the present studies were made. The circled numbers, 1 to 7, indicate the nests of *Eupomotis* in the order constructed. The contour lines indicate the depth of water in inches. See text for explanation.

encroached on the older nest 3 and 2 respectively. While nest 5 did not encroach on nest 1, it closely approached it; but nest 5 was built while there were eggs in nest 1. Nest 4 split the distance between nest 2 and nest 3, but we have reason to believe that 2 and 4 were made by the same fish, as they were alternately worked by one male. Thus it is apparent that the only available areas suited to these fish in this pool are in the upper tips of the two arms. The contour lines show why this should be so, for at all other places the shore line is too steep for sunfish to build nests, and apparently under the conditions in this pool they seek water between 6" and 12" in depth. The gravel bottom made nesting a simple matter of cleaning off such fine detritus as might be present. Not much of a "dish" could be formed as the large size of the gravel precluded much shifting by the efforts of these small fish.



Text-figure 2.

The nests of *Ameiurus* of the previous year in the same pool. (After Breder, 1939). The circled numbers, 1 to 3, indicate the catfish nests in the order constructed. Differences in the symbols for aquatic plants, et cetera, indicate the only changes in the pool between the two years. See text for explanation.

TABLE I.

Schedule of Events in Reproducing *Eupomotis*.

Dates	NEST NUMBER.							EVENTS.	TEMPERATURE °C.	
	1	2	3	4	5	6	7		AIR	WATER
May 5								14 fish placed in pool.		
18	B							Nest just begun.	23.0	20.0
19		B						Nest begun.		
20										
21										
22										
23										
24	A	A	B					Nest begun.		
25			(1)							
26										
27									25.3	20.0
28										
29										
30		RC	A					Nest #2 reoccupied, courting vigorously.		
31										
June 1										
2										
3										
4	RE							Nest reoccupied, eggs.	25.8	24.8
5	(2) A									
6								Eggs hatched.		
7										
8		RC						Nest reoccupied, courting.	24.8	24.8
9				BC				Nest begun, courting.	24.0	25.3
10										
11										
12										
13	E							2d eggs, young on nest.		
14	L							Young left nest.		
15										
Absent from locality—observations suspended.										
July 14	A	A	Y	A	A	A	A	Young on nest #3. Nests	22.5	21.0
15								#5, 6 and 7 made during absence and abandoned.		
16										
17										
18										
19										
20			L				RE	Young left nest #3. Nest	26.5	21.3
21			A					#7 reoccupied and spawning.		
22										
23										
24										
25										
26										
27										
28										
29										
30										

A Heavy storm this date.

A—nest abandoned. B—nest begun. C—courting. E—eggs present. H—eggs hatched. L—young fish left nest. R—nest reoccupied. Y—young on nest.

(1)—Plate I taken this day.

(2)—Plate II taken this day.

If Text-figure 1 is studied closely it will be seen that the presence of nest 1, because of the conformation of the shore, bottom and plants, precluded another nest in that entire arm except very close to it. The next nest, 2, was built as far from it as the pool allowed, being in the other arm. The third nest, now that the other arm was occupied, also was built in the southern arm and as far from nest 2 as the depth permitted. A consideration of the bottom contours and the desire of these fishes to pick the sunniest places well accounts for this and the preceding positions. With this restriction, the only remaining place for a nest not in contact or encroaching on another is that site on which nest 4 was constructed. After this there remained no other place available in the pool in which a nest could be built remote from one already constructed. In fact, the only remaining place where overlapping was not necessary was that place selected for nest 5 which was peripheral to nest 1.

When construction had reached this point no further nests could be built in the spaces available except along the south shore of the south arm. This place was apparently entirely out of the question because of shade. The two remaining nests, 6 and 7, were consequently made so close to 3 and 2 respectively that they encroached on the latter as shown. Table I gives the time sequence of these events.

Courting Activities.

An interesting note on the courting activities of these fish was made June 8 on nest 2. Here a female approached and was very vigorous, entering the nest voluntarily and circling the male and nudging the exposed gravel with her snout. She was not feeding but seemed in a high state of sexual excitement. It gave the impression that the activities of the male are largely one of indicating his presence and willingness and of indicating the location of the nest, the female actually doing the "selecting." It would seem that the chasing of females by males is of that nature rather than a matter of "driving" the female over the nest as is usually reported. The latter would seem to be an impossible procedure with all the open water normally available to these fishes. Usually the male is so willing to spawn that this feature is not seen. For some reason this male did not seem to be ready or able to perform his part and finally the female departed.

On June 9 a single male attended both nest 4 and nest 2. While he spent most of his time on the new nest, he did give attention to both, and a tentatively approaching female caused him to display over both, depending on which one she happened to be nearer. At this time another male attempted to reoccupy nest 3, presumably its maker which had abandoned it some time before, but was driven off by the extreme vigor of the proprietor of nests 2 and 4. Nevertheless no eggs resulted from this activity.

Effects of Weather.

As is well known, the activity of sunfish is considerably controlled by temperature and light. This was very evident as may be noted in Table I by the frequent "Abandonments" and "Reoccupations" of nests. In late May and early June there was an unseasonable amount of cloudy weather and chilly days. It is reflected in the activity and lack of activity indicated in this table. That these factors do not completely control sunfish activity is indicated by the lack of exact synchronization of behavior. For example, on May 24 two nests were abandoned and a third begun. Presumably these

vagaries in behavior have to do with variations in the physiological impetus of the various individuals. When fish abandoned their nests they rejoined the general school which would normally have been composed of females alone.

The last nest was abandoned on July 30, on which date a heavy wind and rainstorm did violent local damage, including the felling of a tree across the pool.

Attention to Eggs and Young.

It is certain that at least three of the nests produced young, that is, nest 1 (two batches), nest 3 and nest 7. Later in the season young of four different size groups which corresponded to the spacing of these four hatchings were evident. What happened during the period of personal absence is not entirely clear but family reports indicate that there was no further egg production.

Nest 1, the first to be established and perhaps therefore by the most vigorous male, had at one time both eggs and young of very different ages in the nest. The young left the nest the day after new eggs were deposited. While it is known that sunfish will spawn on repeated days with a number of females, the writer had not previously encountered or seen reports on two batches of such a difference in age.

DISCUSSION.

Compared with the nesting dates on this species recorded by Breder (1936) for the same general region, the present dates agree very well. His early date was May 11, the present May 18; his late date August 14, the present July 30.

The depths selected by the size of fish involved agree perfectly with his Figure 2. The diameters of the nests, about 20 cm., fall in the Pines Lake group of that paper which also happens to be the closest geographically. It will be noted that in the south arm of the pool, the only place where any selection was possible, the nests are ranged along its northern edge, which is what should be expected since the other side is shaded by the south bank. Normally one expects sunfish nests on the north side of a small pond for this reason, as has already been discussed in the earlier paper.

Compared with the catfish which occupied this pool the preceding year (see Text-fig. 2), some curious differences and similarities appear. Sunfish nest 1 occupied exactly the same place as catfish nest 3. In other words, the first choice of the former was the last choice of the latter. The other two catfish nests occupied places in which sunfish would surely not be expected to nest, in a cavity and in a well-sheltered spot. This still leaves unexplained why the one catfish nested in such a sunfish-like manner—at a place which, as a matter of fact, was the first choice of the latter—a choice that might have been guessed on *a priori* grounds. In this connection it should be mentioned that the pool suffered from no limitation of presumably choice catfish nesting sites, but that they did nest as remote from each other as practicable. This wide selection of sites was not true in the case of the sunfish which were strictly limited as to suitable sites, and indeed the pool was a trifle too shaded to be ideal for such a species. Since the first catfish nest occupied a position near the central part of the “U” formed by the pool, the only thing that was left for the other two pairs was to retreat up each arm as far as other factors permitted. Compared with the order of selection exercised by the sunfish, which is indicated in the body of the paper, we actually have a similar type of centrifugal influence expressed in two very different kinds of nest building fishes. These sunfish nests compared with those

of Pines Lake (Breder, 1936) show thoroughly comparable selective reactions. The remaining data in the body of the paper are confirmatory of those in the earlier study.

SUMMARY.

1. Earlier studies on *Eupomotis* are confirmed under semi-controlled conditions.
2. A comparison is made between the nesting habits of *Eupomotis* and *Ameiurus* under identical conditions in which it is seen that the first choice of one was the last choice of the other.
3. The role of nesting males in pursuing females is indicated to be indicative of his presence and willingness to mate, rather than an overpowering effect.
4. Males may operate, intermittently, over two close nests.
5. Selection of nesting sites of *Eupomotis* and *Ameiurus* is shown to be controlled by a centrifugal influence between nesting individuals, modified by the limitations of the availability of suitable nesting sites.

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1936. The Reproductive Habits of the North American Sunfishes (Family Centrarchidae). *Zoologica* 21 (1): 1-48.
1939. Variations in the Nesting Habits of *Ameiurus nebulosus* (Le Sueur). *Zoologica* 24 (25): 367-378.

EXPLANATION OF THE PLATES.

PLATE I.

Nest 3 on May 25. See Table I. This nest was begun the day previous. It was impossible to photograph the nest groups, due to difficult lighting conditions and interfering vegetation.

PLATE II.

Nest 1 on June 5. See Table I. This shows the nest on the day after the first batch of eggs was laid.



THE NESTING BEHAVIOR OF EUPOMOTIS GIBBOSUS (LINNAEUS)
IN A SMALL POOL.



THE NESTING BEHAVIOR OF EUPOMOTIS GIBBOSUS (LINNAEUS)
IN A SMALL POOL

24.

Reproductive Activities of a Hybrid Minnow, *Notropis cornutus* × *Notropis rubellus*.

EDWARD C. RANEY

Department of Zoology, Cornell University, Ithaca, New York.

A considerable number of natural hybrids have been recognized in recent years among American Cyprinidae. One of the most common is the cross between the common shiner and the rosy-faced shiner, *Notropis cornutus* (Mitchill) × *Notropis rubellus* (Agassiz). The subspecies of *Notropis cornutus* involved appears to be unimportant and hybrids of *Notropis rubellus* with subspecies *cornutus*, *frontalis* and *chrysocephalus* have been found occasionally throughout their range. Hubbs & Brown (1929, p. 37) have pointed out that hybrids of this combination were misidentified as *Notropis pulsbryi* by Forbes & Richardson (1909, p. 149).

It has generally been assumed that the hybridization in this as well as in other minnow combinations is due to chance fertilization. The breeding habits of *Notropis cornutus* and *Notropis rubellus* in some localities are such that they are thrown into close contact at the spawning time. Both species may utilize an unprepared gravel bottom in running water for breeding but appear to prefer the pebble nests of the river chub, *Nocomis micropogon*, and the horny-headed chub, *Nocomis biguttatus*, when these are available. However, *Notropis cornutus* is quite adaptable and has been observed (Raney, 1940, p. 6) digging a shallow nest in riffles. In the reported observations of *cornutus* and *rubellus* spawning in close proximity, it has been over a *Nocomis* nest. Hubbs & Brown (1929, p. 37) "observed *rubellus* mating in midwater a few inches over the heads of breeding *cornutus*." They also noted that this hybrid combination was most common below obstructions where a large number of *cornutus* and a considerably smaller population of *rubellus* were present. This is in agreement with my observations in Catatonk Creek at Candor, New York, (Susquehanna Drainage), where many hybrids have been collected and numerous others seen in an area of gravel riffles below an impassable dam. At this locality practically all of the spawning of *rubellus* and much of that of *cornutus* takes place over the nests of *Nocomis micropogon*. The use of *Nocomis* nests by *Notropis cornutus* or *Notropis rubellus* has been reported by Greeley (1929, p. 172, and 1938, p. 67), Hankinson (1932, p. 417), Hubbs & Brown (1929, p. 37), Hubbs & Cooper (1936, p. 49), Raney & Lachner (1939, p. 160) and Raney (1940, p. 7). Hankinson (1932, p. 417) describes the breeding behavior of *rubellus* as follows: "Spawning could be seen among these rosy-faced minnows since it always took place high above the other fish of the aggregation (mostly *cornutus*) and several inches above the gravel. The males would collide with the females, striking them on or near the head with their roughened snouts, and the two would contort themselves in a way that suggested spawning."

Several times in the past few years, during late May and early June, both *cornutus* and *rubellus* and hybrids between them have been observed

over *Nocomis* nests. The hybrids of both sexes appeared to be in a condition of sexual ripeness. The nuptial tubercles were well developed in the males, and they showed the red colors that are apparent in the breeding season. The females contained well developed eggs and some of them showed red nuptial colors and tubercles. A suspicion that these hybrids were capable of spawning was confirmed during the past spring (1939) when a number were seen performing the breeding act.

RECOGNITION IN THE FIELD.

The recognition of these hybrids in the field became relatively easy after one had watched them for many hours. The hybrids were intermediate in body shape between the parent species, *cornutus* and *rubellus*, and could be distinguished by this character alone. The spawning hybrids were slightly larger than any male *rubellus* seen at this locality. However, the breeding color of the males furnished the best clue to their identification. The following color characters (not apparent in preserved specimens) were noted in breeding males when viewed under water under natural conditions.

<i>Notropis c. cornutus</i>	Hybrid	<i>Notropis rubellus</i>
The mid-dorsal stripe and the stripe on each side of the back were conspicuous and varied from a bright silver to a light green against the dark background of the back. These stripes were outstanding highlights and could be seen at a considerable distance. The snout was dusky.	The stripes were easily seen but were red. The snout was slightly red.	The stripes were absent or indistinct and the anterior half of the body was bright red. The snout was bright red.

The following brief color descriptions of males were taken after several hours' preservation in 10 per cent. formalin. In *Notropis c. cornutus* the sides, the branchiostegal region and at times the lower part of the cheek and opercle, the paired fins, and the outer or posterior border of the median fins were red. The upper parts of the cheek and opercle were a slate blue as was a narrow band immediately behind the opercle. The back was nearly black, with the mid-dorsal and lateral light stripes mentioned above.

In the hybrid, *Notropis c. cornutus* \times *Notropis rubellus*, the sides, branchiostegal region, the lower cheek and opercle, the back at the base of the dorsal fin, the pectoral and to a lesser extent the pelvic and anal fins were red.

In *Notropis rubellus* the snout, chin, top of head, anterior half of body, the base of the dorsal fin, the base of the pectoral fins and to a lesser degree the base of the ventral fins were red.

The degree of development of breeding tubercles in the male hybrids is interesting as they appear to have both the pattern and size of the tubercles possessed by both the parent species. In ripe males of *rubellus* many small tubercles cover the chin, snout, top and side of head, upper two-thirds of the opercle, and the posterior edge of almost every scale on the back and upper sides. All fins are covered with small tubercles. They are best developed on the upper sides of the pectoral fin and least developed on the anal fin. In males of *cornutus* there are fewer but larger and sharper tubercles on the chin, snout, top of the head, and on the back in front of the dorsal fin. A few minute tubercles are found on the upper sides. In male hybrids there are many fine tubercles at approximately the same positions on the body and fins as in the parent species. There are also several dozen larger tubercles on the top of the head, as in *cornutus*.

SPAWNING OF HYBRIDS.

Observations of spawning hybrids were made on June 10, 1939, in Catatonk Creek, two miles south of Candor, New York. On this date *Notropis c. cornutus* had about reached the end of its breeding season and no spawning males of this species were seen (the spawning season had reached its peak about June 1, when practically every *Nocomis* nest was occupied by 5 to 25 *cornutus* males). Many ripe adults of *Notropis rubellus* were seen over the same *Nocomis* nests, but were also seen as late as June 10 spawning over gravel shallows in riffles.

At 5 P.M. on June 10, when the water temperature was 69° F., the air 66° F., a group of hybrids, *Notropis c. cornutus* × *Notropis rubellus*, was seen over a nest of *Nocomis micropogon* (the only species of *Nocomis* found in Catatonk Creek). The nest, roughly two feet in diameter, consisted of stones up to two inches in diameter piled to a height of four inches above the general level of the gravelly creek bottom. It was located in moderately swift water at a depth of 10 inches. The stream at this point was 70 feet wide and the nest was about 25 feet from shore. Many *Nocomis* nests were available in this area of Catatonk Creek but few were located in as fast a riffle as this particular one and relatively few were occupied by spawning fish at this late date.

At various times, from 10 to 16 male hybrids ranging in standard length from 65 to 75 mm. (as determined by measuring captured specimens) were seen facing upstream over the *Nocomis* nest. They attempted to maintain a definite position and generally an individual did not move more than five inches in any direction. They alternately moved to right and left a few inches and, in general, their behavior was similar to that of spawning *rubellus*, males of which hold positions facing upstream, shifting to either side and striking an adjacent male from time to time but not moving far from the original position. The *rubellus* and hybrid males differed in behavior from those of *cornutus* mainly in that they did much less fighting for position and did not drive away predators slightly larger than themselves.

Many *cornutus* females were observed below the nest, occasionally coming up over the males and, at times, continuing upstream in front of the nest. A number of individuals of both sexes of *rubellus* were seen both over the downstream half of the *Nocomis* nest and over the gravel below the nest but they were not observed spawning although the males jockeyed some for position. The *rubellus* males and females occupied a slightly higher stratum than the *cornutus* females and the hybrids, which were down over the pebbles of the nest so that the lower fins at times appeared to be in contact with the bottom.

The spawning act was identical with that observed for *cornutus* as recently reported in detail (Raney, 1940). A female *cornutus* came upstream over a hybrid male and dipped down to lie along side him. He threw his caudal peduncle over hers and lifted his pectoral fin which was inserted underneath the front end of her body. This activity forced her firmly against the bottom of the nest, where she rested on her side with her vent facing upstream. The eggs were forced out at the moment that the male's body was thrown into a curve. The breeding act was over in less than a second. The female then swam downstream several feet but later returned to spawn with the same or another male. The male hybrid remained at the same place and was able to spawn again immediately. The breeding act was noted a dozen times within 15 minutes, and the details were observed clearly from a distance of about four feet. No female hybrids were observed at this *Nocomis* nest.

Upon the completion of a spawning act several small fallfish, *Leucosomus corporalis*, dashed to the spot and dug vigorously among the pebbles for eggs. Several times male hybrids were also seen standing on their heads as

if attempting to eat eggs. This behavior may, however, be a primitive type of digging activity such as is developed to a greater degree in *cornutus* males. A search revealed many eggs among and under the pebbles of the nest. Eggs of both *Notropis cornutus* and *Nocomis micropogon* were found, indicating that the nest had been utilized for some time. However, it was impossible to isolate the eggs from a single mating under natural conditions and, as yet, I have been unable to hatch *cornutus* eggs and raise the young. With rare exceptions the *cornutus* females were larger than the hybrid males with which they spawned. Males of *cornutus* probably spawn occasionally with a larger female, but I have not seen it happen in many observations over a period of years. After observing these spawning hybrids for nearly an hour, as many as could be captured were preserved and their identification checked.

On a previous occasion a male *cornutus* was seen spawning with a female hybrid. This observation was also made in Catatonk Creek, just below Candor, on May 31, 1939. At 2:30 P. M. a group of about 30 large *cornutus* males were holding positions over a *Nocomis* nest. About a dozen individuals of *rubellus* were present over the lower side and below the nest. At one time five hybrids were seen occupying the same area, mingling with *rubellus*. A female hybrid which had some red coloration on the anterior third of the body came up over a male *cornutus*, dipped down beside him and went through a spawning act in a manner apparently identical to that followed by a female *cornutus*. No repetitions of this spawning act took place during several hours of observation, although *cornutus* spawned freely throughout the afternoon.

DATA FROM HYBRIDS.

An examination of 18 *cornutus* \times *rubellus* hybrids specimens collected over a period of five years in a two-mile stretch of stream of Catatonk Creek below Candor gives some interesting results. These specimens (in the Cornell University Museum) were mostly taken from early May through June, and they could easily be sexed by an examination of the gonads. The sexes were equally divided among these 18 specimens, and all but one small male (60 mm. in standard length) appeared to be capable of producing sex elements. Dr. Carl L. Hubbs informs me that he, too, has found a normal sex ratio in *cornutus* \times *rubellus* hybrids, and that these hybrids often show gonads which appear to be ripe and normally developed.

These data are interesting in the light of results obtained from a study of aquarium-produced and natural hybrids of sunfishes as reported by Hubbs & Hubbs (1933), who found several combinations of hybrid sunfishes to be predominantly males (81 to 95 per cent.). The evidence also indicated that the resulting hybrids were sterile. Bailey & Lagler (1938, p. 605) also found a predominance of males (80 to 96 per cent.) in a sample of natural hybrid sunfishes. However, a recently studied collection of a hitherto unreported hybrid sunfish, *Lepomis auritus* \times *Lepomis cyanellus*, taken by Dr. A. H. Wright in a pond along the South Branch of the Potomac River, one mile above Franklin, Pendleton Co., West Virginia, on August 14, 1931, shows an altered sex ratio in favor of the females. In this collection (examined by both Dr. Carl L. Hubbs and Dr. Reeve M. Bailey) there were 6 male and 18 female hybrids (25 per cent. males). In this same collection there were 17 males and 14 females of *Lepomis auritus* and 14 males and 17 females of *Lepomis cyanellus*. There also appeared to have been some back-crossing, as some of the hybrids strongly approached *Lepomis auritus*.

There is no direct proof that either males or females of the *cornutus* \times *rubellus* hybrids are fertile. However, as has already been mentioned, each sex may perform the spawning act in nature with *cornutus*. Possibly the hybrids may spawn with one another, although this act has not as yet been

observed. Male hybrids have been forced to emit milt upon pressure. The fact that some hybrids appear to be closer in characters to one parent species suggests that they may have resulted from a back cross. Hubbs & Brown (1929, p. 36) reported "our large number of specimens (hybrids) from numerous localities completely bridge over the wide gap in characters between the two parent species." These data also suggest that at times the breeding act involving a hybrid and one of the parent species may be successful.

There is considerable variation in the condition and position of the eggs in the ovary of hybrids taken during May and June. In some the eggs are all enlarged and appeared much as they do in either *cornutus* or *rubellus* females which are ready for spawning. In a few ovaries the eggs are very small and it appears that they would ripen much too late, if at all, for the spawning season. In a few hybrids, for example one 73 mm. in standard length taken on October 18, 1938, several unusually large eggs occur at intervals among many small eggs. It seems that these fish may have retained some eggs from the previous spring.

TABLE I.

Length-frequency distribution of mature hybrids, *Notropis c. cornutus* × *Notropis rubellus* and *Notropis rubellus* taken during May and June from Catatonk Creek, below Candor, New York.

Standard Length in mm.	Hybrids: <i>Notropis c. cornutus</i> × <i>Notropis rubellus</i>		<i>Notropis rubellus</i>	
	Female	Male	Female	Male
44	...	...	...	2
46	...	...	...	4
48	...	...	1	5
50	..	...	3	4
52	...	..	4	1
54	...	...	1	2
56	..	...	1	...
58	...	...	2	1
60	...	1	1	...
62	...	1	6	...
64	...	1	5	...
66	...	...	1	...
68	...	..	...	...
70	...	2	...	...
72	1	..	...	...
74	...	1	...	...
76	1	1	...	...
78	3	1	...	...
80	...	1	...	...
82	1	...	...	...
84	1	...	...	...
86	...	...	...	...
88	1	..	...	...
90	...	...	...	...
92	1	...	...	...
Number	9	9	25	19
Mean	80.89	70.44	58.00	48.95
Standard Deviation	6.24	7.24	5.77	3.57

*Immature.

Some of the female hybrids had tubercles and some red color on the anterior part of the body but the majority had neither tubercles nor color. Females as well as the males of *rubellus* are tuberculate at the spawning time, and both develop red color. A female *rubellus* in nuptial color is illustrated in Greeley (1930, plate 10). However the male *rubellus* is more brightly colored and has more of the body covered with tubercles. In *cornutus* the female is rarely colored and then usually only on the posterior border of the caudal and anal fins, and she rarely, if ever, has breeding tubercles.

The male hybrids taken during May and June had the breeding color and breeding tubercles well developed. The one exception was a small individual, 60 mm. in standard length, which was sexed without question as a male but was apparently immature. In the hybrids the lips were dusky as in *rubellus*, rather than light colored as in *cornutus*.

As in *rubellus*, the females of the hybrids attain a greater length than the males. Table I gives the length-frequency distribution of 18 hybrids from Catatonk Creek below Candor, New York, collected from early May through June over a period of five years. Length measurements of a random sample of 44 specimens of *Notropis rubellus* in spawning condition, collected at the same locality on June 10, 1939, are included. Seventeen additional hybrids were secured during October, 1938 and 1939, but since most of these specimens were difficult to sex with accuracy they are not included here. However all measurements of these October specimens fell within the range as given in Table I. In *cornutus* the males attain a greater length than the females as reported by Raney (1940, p. 5).

One large hybrid specimen placed in an aquarium in October, 1939, proved to be extremely hardy and outlived several hundred specimens of *cornutus* and *rubellus* placed in similar containers under similar conditions. Not only did he outlive all of the specimens of the parent species, but a dozen other species of cyprinids as well, and is thriving and active at the present time (June, 1940).

SUMMARY.

1. Hybrids between *Notropis rubellus* and several sub-species of *Notropis cornutus* are fairly common in some localities, especially below dams and over *Nocomis* nests during the spawning season in late May and early June.

2. The hybrids apparently result from a chance combination of sexual elements as the parent species spawn at the same spot.

3. Hybrids can be recognized in the field by such characters as body shape and coloration. Male hybrids have well developed tubercles and red colors, as do some female hybrids.

4. Several male hybrids, *Notropis c. cornutus* × *Notropis rubellus*, were observed spawning with female *Notropis c. cornutus* over a pebble nest of *Nocomis micropogon*. On another occasion a female hybrid went through the spawning process with a male *Notropis c. cornutus*.

5. The actual breeding behavior of male hybrids is identical with that of *Notropis cornutus* although their behavior over a nest is similar to that of *rubellus*. Eggs were deposited by *cornutus*. Many hybrids have seemingly normal eggs and milt has been obtained from male hybrids upon stripping.

6. The sexes were evenly divided between 18 hybrids collected during the breeding season over a period of five years.

7. Female hybrids attain a significantly greater maximum and mean standard length than males. This is also true of female *rubellus* but in *cornutus* the males are larger.

8. One hybrid kept in an aquarium over winter appeared to be an unusually hardy individual, outliving all specimens of parent species kept in similar containers under similar conditions.

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25.

Eastern Pacific Expeditions of the New York
Zoological Society. XXII.

Mollusks from the West Coast of Mexico and Central America.

Part I.¹

LEO GEORGE HERTLEIN & A. M. STRONG

California Academy of Sciences.

(Plates I & II).

[This is the twenty-second of a series of papers dealing with the collections of the Eastern Pacific Expeditions of the New York Zoological Society made under the direction of William Beebe. The present paper is concerned with specimens taken on the Templeton Crocker Expedition (1936) and the Eastern Pacific Zaca Expedition (1937-1938). For data on localities, dates, dredges, etc., refer to *Zoologica*, Vol. XXII, No. 2, pp. 33-46, and Vol. XXIII, No. 14, pp. 287-298.]

CONTENTS.

	Page		Page
Introduction	370	<i>Nucula chinacoma</i> Dall	385
Class Polycypoda	373	<i>Nucula colombiana</i> Dall	385
Order Prionodermacea	373	<i>Nucula grayi</i> d'Orbigny	385
Superfamily Solemyacea	373	<i>Nucula phigewa</i> Dall	386
Family Solemyidae	373	<i>Nucula panamua</i> Dall	386
Genus <i>Solemya</i> Lamarck	374	<i>Nucula paysonis</i> A. Adams	386
Subgenus <i>Acharax</i> Dall	375	<i>Nucula poyatitae</i> Dall	386
<i>Solemya (Acharax) agassizi</i>	375	<i>Nucula risum</i> Sowerby	387
Dall	375	<i>Nucula sacatieri</i> Mabille & Roehchrone	387
<i>Solemya (Acharax) johnsoni</i>	376	<i>Nucula taeniolata</i> Dall	387
Dall	376	<i>Nucula tanneri</i> Dall	388
<i>Solemya (Acharax) macrodactyla</i> Mabille & Roehchrone	376	Genus <i>Acda</i> H. & A. Adams	388
<i>Solemya (Acharax) patagonica</i>	377	Subgenus <i>Truncacda</i> Schenck in Grant & Gale	388
F. A. Smith	377	<i>Acda (Truncacda) castrosensis</i>	388
Subgenus <i>Petrasma</i> Dall	377	Hinds	388
<i>Solemya (Petrasma) panamensis</i>	377	Family Nuculanidae	389
Dall	377	Genus <i>Nuculana</i> Lmk	390
<i>Solemya (Petrasma) radialis</i>	378	Subgenus <i>Saccella</i> Woodring	392
Carpenter	378	<i>Nuculana (Saccella) acuta</i>	392
Superfamily Nuculacea	378	Conrad	392
Family Nuculidae	378	<i>Nuculana (Saccella) callimene</i>	393
Genus <i>Nucula</i> Lamarck	379	Dall	393
<i>Nucula (Nucula) declivis</i> Hinds	380	<i>Nuculana (Saccella) ctenensis</i>	393
<i>Nucula (Nucula) exigua</i>	381	Sowerby	393
Sowerby	381	<i>Nuculana (Saccella) eburnea</i>	395
Subgenus <i>Ennucula</i> Iredale	382	Sowerby	395
<i>Nucula (Ennucula) tenuis</i>	382	<i>Nuculana (Saccella) gibbosa</i>	395
Montagu	382	Sowerby	395
<i>Nucula (Ennucula) caidara</i>	383	<i>Nuculana (Saccella) impar</i>	396
Dall	383	Pilsbry & Lowe	396
<i>Nucula (Ennucula) linki</i> Dall	383	<i>Nuculana (Saccella) lacrimadus</i>	396
Subgenus <i>Nucolopsis</i> Woodring	383	Pilsbry & Lowe	396
<i>Nucula (Nucolopsis) schencki</i>	384	<i>Nuculana (Saccella) taphrus</i>	397
Hertlein & Strong, n. sp.	384	Dall	397
Subgenus uncertain:			
<i>Nucula apujana</i> Dall	384		

¹ Contribution No. 607, Department of Tropical Research, New York Zoological Society.

CONTENTS (continued):

	Page		Page
Subgenus <i>Politoleda</i> Hertlein & Strong, n. subg.	397	<i>Yoldia</i> (<i>Megayoldia</i>) <i>martyria</i> Dall	414
<i>Nuculana</i> (<i>Politoleda</i>) <i>polita</i> Sowerby	397	Subgenus <i>Orthoyoldia</i> Verrill & Bush	414
Subgenus <i>Costelloleda</i> Hertlein & Strong, n. subg.	398	<i>Yoldia</i> (<i>Orthoyoldia</i>) <i>panamensis</i> Dall	415
<i>Nuculana</i> (<i>Costelloleda</i>) <i>costellata</i> Sowerby	398	Subgenus <i>Yoldiella</i> Verrill & Bush	415
<i>Nuculana</i> (<i>Costelloleda</i>) <i>marella</i> Hertlein, Hanna & Strong, n. sp.	399	<i>Yoldia</i> (<i>Yoldiella</i>) <i>cecunella</i> Dall	416
Subgenus <i>Thestyloda</i> Iredale	400	<i>Yoldia</i> (<i>Yoldiella</i>) <i>chilensis</i> Dall	416
<i>Nuculana</i> (<i>Thestyloda</i>) <i>hamata</i> Carpenter	400	<i>Yoldia</i> (<i>Yoldiella</i>) <i>dicella</i> Dall	416
<i>Nuculana</i> (<i>Thestyloda</i>) <i>cordyla</i> Dall	401	<i>Yoldia</i> (<i>Yoldiella</i>) <i>granula</i> Dall	416
Subgenus <i>Spinula</i> Dall	401	<i>Yoldia</i> (<i>Yoldiella</i>) <i>indolens</i> Dall	417
<i>Nuculana</i> (<i>Spinula</i>) <i>calcar</i> Dall	401	<i>Yoldia</i> (<i>Yoldiella</i> ?) <i>infrequens</i> Dall	417
<i>Nuculana</i> (<i>Spinula</i>) <i>calcarella</i> Dall	401	<i>Yoldia</i> (<i>Yoldiella</i>) <i>leanilla</i> Dall	417
Subgenus <i>Jupiteria</i> Bellardi	402	<i>Yoldia</i> (<i>Yoldiella</i> ?) <i>montana</i> Dall	417
Subgenus uncertain:		Genus <i>Cyrella</i> A. Adams	418
<i>Nuculana</i> <i>acrita</i> Dall	402	<i>Cyrella</i> <i>montana</i> Carpenter in Dall	419
<i>Nuculana</i> <i>agapica</i> Dall	402	Subgenus <i>Neopleurodon</i> Hertlein & Strong, n. subg.	419
<i>Nuculana</i> <i>bicostata</i> Sowerby	403	<i>Cyrella</i> (<i>Neopleurodon</i>) <i>subdolosus</i> Strong & Hertlein	420
<i>Nuculana</i> <i>crispa</i> Hinds	403	Genus <i>Malletia</i> Desmoulin	420
<i>Nuculana</i> <i>cuneata</i> Sowerby	403	<i>Malletia</i> (<i>Malletia</i>) <i>chilensis</i> Desmoulin	421
<i>Nuculana</i> <i>excavata</i> Hinds	404	Subgenus <i>Nepo</i> H. & A. Adams	422
<i>Nuculana</i> <i>hindsii</i> Hanley	404	<i>Malletia</i> (<i>Nepo</i>) <i>gomara</i> Dall	422
<i>Nuculana</i> <i>lobula</i> Dall	404	Subgenus <i>Minormalletia</i> Dall	422
<i>Nuculana</i> <i>loshka</i> Dall	404	<i>Malletia</i> (<i>Minormalletia</i>) <i>arceiformis</i> Dall	423
<i>Nuculana</i> <i>lucasana</i> Strong & Hertlein	405	<i>Malletia</i> (<i>Minormalletia</i>) <i>benethima</i> Dall	423
<i>Nuculana</i> <i>ornata</i> d'Orbigny	405	Subgenus uncertain:	
<i>Nuculana</i> <i>oria</i> Dall	405	<i>Malletia</i> <i>fabia</i> Dall	423
<i>Nuculana</i> <i>peruviana</i> Dall	405	<i>Malletia</i> <i>inequalis</i> Dall	423
<i>Nuculana</i> <i>pontonia</i> Dall	406	<i>Malletia</i> <i>magellanica</i> E. A. Smith	424
<i>Nuculana</i> <i>rhyncha</i> Dall	406	<i>Malletia</i> <i>patagonica</i> Mallet & Rochebrune	424
Genus <i>Adrana</i> H. & A. Adams	406	<i>Malletia</i> <i>peruviana</i> Dall	424
<i>Adrana</i> <i>arcuata</i> Sowerby	406	<i>Malletia</i> <i>truncata</i> Dall	424
<i>Adrana</i> <i>crenifera</i> Sowerby	406	Genus <i>Tindaria</i> Bellardi	425
<i>Adrana</i> <i>elongata</i> Sowerby	409	Subgenus <i>Tindariopsis</i> Verrill & Bush	425
<i>Adrana</i> <i>exoptata</i> Pilshry & Lowe	409	<i>Tindaria</i> (<i>Tindariopsis</i>) <i>subulata</i> Gould	425
<i>Adrana</i> <i>penascoensis</i> Lowe	410	Subgenus uncertain:	
<i>Adrana</i> <i>sowerbiana</i> d'Orbigny	410	<i>Tindaria</i> <i>atossa</i> Dall	426
<i>Adrana</i> <i>suprema</i> Pilshry & Olsson	411	<i>Tindaria</i> <i>compressa</i> Dall	426
<i>Adrana</i> <i>taylori</i> Hanley	412	<i>Tindaria</i> <i>panamensis</i> Dall	426
<i>Adrana</i> <i>tonosiana</i> Pilshry & Olsson	412	<i>Tindaria</i> <i>mixana</i> Dall	427
Genus <i>Yoldia</i> Moll	412	<i>Tindaria</i> <i>salara</i> Dall	427
Subgenus <i>Katadesmia</i> Dall	413	<i>Tindaria</i> <i>smirna</i> Dall	427
<i>Yoldia</i> (<i>Katadesmia</i>) <i>vincola</i> Dall	413	<i>Tindaria</i> <i>thia</i> Dall	427
Subgenus <i>Megayoldia</i> Verrill & Bush	414	<i>Tindaria</i> <i>virans</i> Dall	428

INTRODUCTION.

Two expeditions to the eastern tropical Pacific were conducted by Mr. Templeton Crocker and Dr. William Beebe under the auspices of the New York Zoological Society. The means of transportation for these trips was Mr. Crocker's yacht *Zaca*. The first of these left San Diego, California, on March 19, 1936. Dredgings were made at many localities from a short distance south of San Diego to Cape San Lucas and into the Gulf of California, north to Santa Inez Bay. Clarion Island in the Revillagigedo group was also visited and some dredgings and shore collections made. At certain places shore collecting was conducted but a large part of the mollusks obtained by this expedition resulted from dredging, mostly from the southern part of the Gulf of California. The depth varied from 1 to 600 fathoms but most of the collection was obtained in less than 100 fathoms. This expedition returned to San Diego, California, on May 25, 1936. A paper by Beebe² contains an itinerary, list of stations and nets and dredges used, and a general

² Beebe, W. The Templeton Crocker Expedition. II. Introduction, Itinerary, List of Stations, Nets and Dredges. *Zoologica, Sci. Contrib. New York Zool. Soc.*, Vol. 22, pt. 1, April 5, 1937, pp. 33-46, 8 text figs.

account of the trip by the same author³, appeared in a book entitled "Zaca Venture."

The second expedition by Messrs. Crocker and Beebe left San Diego, California, on November 6, 1937. This cruise took the *Zaca* along western Lower California and the west coast of Mexico as far south as Gorgona Island, Colombia. Dredging and shore collecting on this trip yielded much fine research material. The *Zaca* returned to California and the party disbanded at Balboa on April 5, 1938. An account of the itinerary, list of stations, nets and dredges on this trip is contained in a paper by Beebe⁴.

The present collections, then, are almost entirely from tropical and sub-tropical western North and Central America between 30° and 3° North Latitude. Collecting over such an extensive area has naturally brought to light many interesting occurrences, and a number of new species.

Several important extensions in range were discovered during the work. Especially noteworthy are those species heretofore known from more northern latitudes but now found to range south to Cape San Lucas. Also, numerous species, previously known to occur in more southern latitudes were found in the Gulf of California. An illustration of this is the discovery in the Gulf of *Cancellaria cumingiana* Petit, heretofore known only from Ecuador. Another interesting occurrence is that of a single valve of *Cardium magnum* Linnaeus, a species well known off Florida, which was found at Santa Inez Bay. It seems possible that this may have been transported to the west coast by some fortuitous means.

Through an arrangement with Dr. Beebe the mollusks were submitted to the authors for identification and description. Types of new species and figured specimens have been deposited in the type series of the California Academy of Sciences; duplicates of some of the other species and certain unique specimens were retained in the same institution for the purpose of comparative studies of tropical west American mollusks now under way by the authors. The bulk of the collection accompanied by identifications has been returned to Dr. Beebe of the New York Zoological Society.

Numerous papers contain records of species inhabiting the Gulf of California but the present collection revealed many additional ones not heretofore known to live in that region. There are also a very considerable number of forms previously unknown. Although it has been generally recognized that the Gulf of California contains one of the richest known molluscan faunas, the meticulous care taken by Messrs. Crocker and Beebe in recording locality data makes this collection one of the most important ever made in the area.

SCOPE AND PLAN OF PRESENT REPORT.

The preparation of a paper on the present collections offered problems which have required considerable time. No checklist containing the majority of the species known to occur between San Diego and Panama has been published. Several papers dealing with the mollusks of this region exist but any systematic work required consultation of many scattered references and even in these many species have never been illustrated. After due consideration and consultation the authors decided to prepare the paper with the idea in mind that it should be useful not only as a checklist of the present collection but also containing references and illustrations. We therefore have prepared a systematic report with all pertinent references to each

³ Beebe, W. *Zaca Venture* (Harcourt Brace & Co., New York City, New York). 1938, 303 pp. + I-XVI. 23 illustrations.

⁴ Beebe, W. *Eastern Pacific Expeditions of the New York Zoological Society, XIV. Introduction, Itinerary, List of Stations, Nets and Dredges of the Eastern Pacific Zaca Expedition, 1937-1938. Zoologica, Sci. Contrib. New York Zool Soc., Vol. 23, pt. 3, September 28, 1938, pp. 287-298, (2 maps pp. 290, 291).*

species gathered together in the synonymy. The total lack of a complete checklist of the tropical west American mollusks has necessitated a compilation of all the species known to have been described or cited as occurring in that region. Although it would not be possible in the time available to monograph or even give a critical review of all the species, the great utility of a complete catalogue justifies, in our opinion, the inclusion herein of as complete a census as possible. In some cases we have included additional species which are not known to occur in the tropics but which are related to tropical forms, or which for systematic reasons it seems desirable to include. Keys to the genera of certain of the families, and, where information is adequate, keys to species, have been included. However, in many cases, present knowledge does not justify an attempt to furnish a key. The present unstable nomenclature⁵ of mollusks has led the authors to adopt a conservative course in dealing with nomenclatorial problems in connection with this work. Illustrations are planned for all species represented in the collection which are heretofore unillustrated or of which the illustration is not readily available. The range, type locality, repertory of the type where known to us, collecting stations, notes on the species and descriptions of new species are also included. At present it is planned that the entire work will appear at intervals, each part to include one or more families, beginning with the Pelecypoda. In the final part of the paper we hope to present general observations on the collection as a whole and remarks regarding significant features observed regarding distribution; and if feasible, a bibliography of many of the important papers which it is necessary to consult in a study of mollusks of tropical western North America.

At the beginning of this work it was planned that Dr. G. Dallas Hanna, Curator of the Department of Paleontology of the California Academy of Sciences, could collaborate in this work. Unfortunately the work had only begun when duties called him to Alaska and elsewhere which then left the preparation to the present authors. A few species were described during the early stages of the work and in these we have happily been able to include Dr. Hanna as a co-author.

ACKNOWLEDGEMENTS.

We wish here to thank Mr. Templeton Crocker, owner of the yacht *Zaca*, for his generosity and interest which made this paper possible. His collecting and careful recording of locality data have been of great help in work on this collection. To Dr. William Beebe we extend our thanks for his unfailing interest and cooperation throughout this work. His collecting and recording of locality information is a model of its kind. To Dr. G. Dallas Hanna we extend our thanks for his cooperation and unfailing help in advising us regarding many problems which have arisen during the preparation of the paper. His advice and help have been generously available at all times and are greatly appreciated by the authors. Mr. A. G. Smith, Berkeley, California, Dr. U. S. Grant IV, of the University of California at Los Angeles, and Dr. H. G. Schenck and Dr. A. M. Keen of Stanford University, have furnished information regarding certain of the species. The secretarial work of Miss Winifred O'Neill and Miss Alta Holton and the preparation of photographs by Mr. Frank L. Rogers incident to the preparation of this portion of the report is herewith acknowledged. This was done during the course of Federal Works Progress Administration Project No. 8569.

⁵ Henderson, J. Our Unstable Biological Classification and Nomenclature. Presidential Address, Fourth Annual Meeting of the American Malacological Union at Stanford University, June 25-28, 1934, pp. 1-13.

Other papers useful in dealing with nomenclatorial problems are: Procedure in Taxonomy, including a Reprint of the International rules of Zoological Nomenclature with Summaries of Opinions Rendered to date, completely Indexed. By E. T. Schenk and J. H. McMasters. Stanford University Press, Stanford University, California, 1936, VII + 1-72. Terminology of Types. By D. L. Frizzell. *Amer. Midl. Nat.*, Vol. 14, no. 6, 1933, pp. 637-668.

Class Pelecypoda.

The pelecypods or bivalve shells are well known to collectors and systematists. Oysters and scallops are examples of edible pelecypods of economic importance. Marine species occur in all oceans. The total number is not exactly known but there are perhaps about 8,000 species. They are most numerous on the coasts of continents or on land masses which have formerly been connected with continental land masses. About 500 species are known to occur between Bering Sea and San Diego, California, and at least an equal or greater number exist between San Diego and Peru. The largest of all mollusks is the giant clam, *Tridacna gigas* Linnaeus⁶, which attains a length of 54 inches and a weight of more than 500 pounds. Some excellent manuals used in the classification and general arrangement of pelecypods are those of Tryon⁷, Chenu⁸, Fischer⁹, Woodward¹⁰, Dall¹¹ and Thiele¹². In general, although with some exceptions, we have followed the arrangement used by Dall. The importance of the hinge in classification has been discussed by Neumayr¹³ and by Dall¹⁴. The structure of shells has been discussed by Boggild¹⁵ and others, and the coloration has been discussed by Bennett¹⁶. A useful general bibliography of literature dealing with the Pelecypoda is found in Dall's article on Mollusks in Eastman's Translation of Zittel's Text-book of Palaeontology and in recent papers on bivalves by Haas¹⁷. Additional

Order Prionodesmacea.

Superfamily Solemyacea.

Family Solemyidae.

The family Solemyidae is usually placed first in systematic arrangement of the pelecypods. The shell characters are quite different from the following group, the Nuculidae, and as pointed out by some authors, there is little evidence of relationship between the two groups. The gill-structure of the Solemyidae is believed by some writers to be due probably to specialization and not a remnant of a generalized style.

⁶ See Hedley, C. A Revision of the Australian *Tridacna*. *Rec. Australian Museum*, Vol. 13, no. 4, April 12, 1921, pp. 163-172, pl. 27-34. See especially pp. 168-170. See also *Mem. Australian Mus.* 2, pt. 8, 1899, p. 505, and E. A. Smith, *Proc. Malacol. Soc. London*, Vol. 3, 1898, p. 112.

⁷ Tryon, G. W. Structural and Systematic Conchology. Volume 3, 1884. Pelecypoda, pp. 116-353, pls. 104-133.

⁸ Chenu, J. C. Manuel de Conchylogie, Vol. 2, 1862, pp. 1-199, 1015 figs. in text.

⁹ Fischer, P. Manuel de Conchylogie, 1880-1887, pp. 1-1369, 23 pls. Pelecypodes, pp. 897-1187, pls. 16-23.

¹⁰ Woodward, S. P. Manual of the Mollusca. Reprint of Fourth Edition (1880), 1910, Conchifera, pp. 393-507, pls. 16-23. Ap. to Manual of Mollusca by R. Tate, 1910, Conchifera, pp. 64-81.

¹¹ Dall, W. H. Text-Book of Palaeontology by K. von Zittel. Edited by C. R. Eastman, Vol. 1, 1918. Pelecypoda, pp. 422-507, Figs. 637-836 in text.

¹² Thiele, J. Handbuch der systematischen Weichtierkunde. (Verlag von Gustav Fischer, Jena), Teil 3, 1934. Bivalvia, pp. 782-948, figs. 788-867. Also, Handwörterbuch der Naturwissenschaften, Zweite Auflage, Bd. 1, 1931, Bivalvia, pp. 996-1010, figs. 1-8. See also Bivalvia (Palaeontologie) by E. Jaworski, pp. 1010-1026, figs. 1-43.

¹³ Neumayr, M. Zur Morphologie des Bivalvenschlusses. *Sitzungsber. Akad. Wiss. Wien*, Bd. 88, Abt. 1, 1883, pp. 385-419, 2 pls. --- Beiträge zu einer Morphologischen Eintheilung der Bivalven. *Denkschr. Akad. Wiss. Wien*, Bd. 58, 1891, pp. 701-801.

¹⁴ Dall, W. H. Tertiary Mollusks of Florida. A new classification of the Pelecypoda, etc. *Trans. Wagner Free Inst. Sci.*, Vol. 3, pt. 3, March, 1895, pp. 486-566.

¹⁵ Boggild, G. B. The Shell Structure of the Mollusks. *D. Kgl. Danske Vidensk. Selsk. Skrifter Naturvidensk. og Math. Afd.*, 9 Raekke, II, 2, 1930, pp. 233-325, 15 pls., 10 figs. in text. See also Schenck, H. G., Literature on the Shell structure of Pelecypods. *Bull. Mus. Hist. Nat. Belg.*, Vol. 10, no. 34, 1934, pp. 1-20.

¹⁶ Bennett, E. W. Coloration of Mollusca in relation to Light. *Rec. Canterbury Mus.*, Vol. 3, no. 3, November 23, 1928, pp. 185-197.

¹⁷ Haas, F. Bivalvia (Muscheln). H. G. Bronns Klassen und Ordnungen des Tier-reichs, Bd. 3, Abt. III, 1 Lfrg., Leipzig, 1929, pp. 1-176; Bd. 3, Abt. III, 2 Lfrg., 1929, pp. 1-292. With bibliography; Bd. 3, Abt. III, 3 Lfrg., 1931, pp. 177-384; Bivalvia. Dr. H. G. Bronns Klassen und Ordnungen des Tier-reichs, Bd. 3, Abt. III, 4 Lfrg., Leipzig, 1933, pp. 385-544. Also pp. 12-141. Short bibliography; Bd. 3, Abt. III, 1 Lfrg., 1937, pp. 1-208; Bd. 3, Abt. III, 2 Lfrg., 1938, pp. 209-466.

references which deal with the fauna upon which this paper is based will be found in succeeding pages.

Genus *Solemya* Lamarck.

Solemya Lamarck, Anim. s. Vert., Vol. 5, 1818, p. 488. Species in original list: *Solemya australis* and *Solemya mediterranea*. —Dall, *Nautilus*, Vol. 22, no. 1, May, 1908, p. 1. "Type *S. australis* Lamarck." —Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 361. *S. australis* Lamarck considered to be the type. —Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 109. Type: *Solenomya mediterranea* Lamarck=*Solemya mediterranea* Lamarck=*Solemya togata* (Poh).

Solenimya Lamarck, Bowdich, Elem. Conch., Pt. 2, 1822, p. 8. "*Solenimya*. (*Solemya*. Lam.) M." Sole species: *Solenimya australis* cited as fig. 17.

Solenomya Lamarck, Menke, Synop. Meth. Moll., 1830, p. 119. ("*Solemya*, Lam.") Sole species: *Solenomya mediterranea* Lamarck. —Children, *Quart. Jour. Lit. Sci. and Arts*, Vol. 14, January 1823, p. 300 (reprint p. 27). Reprint by Kennard, Salisbury and Woodward, *Smithson. Misc. Coll.*, Vol. 82, no. 17, July 11, 1931, p. 7. Type species: *S. mediterranea* Lamarck.

Type (designated by Children): *Solenomya mediterranea* Lamarck. [= *Solemya mediterranea* Lamarck, Anim. s. Vert., Vol. 5, 1818, p. 489. Ref. to "Poli, test. 2, p. 42, et vol. 1. tab. 15, f. 20"; "Solen. Encycl. pl. 225, f. 4." "Habite la Méditerranée, dans le sable." Referred to *Solenomya togata* Poli by Bucquoy, Dautzenberg & Dollfus, *Moll. Mar. Roussillon*, Vol. 2, 1898, p. 718, pl. 92, figs. 8, 9, 10. Mediterranean; Adriatic; Atlantic; Senegal; Madeira].

Shell elongate, *Solen*-shaped, gaping at each end, epidermis dark, horny and extending beyond the ventral margins; umbos posterior; ligament amphidetic, chiefly internal; hinge edentulous with an obliquely inclined chondrophore, below which is an internal rib on the inner surface of the valve; pallial line obscure. Outer layer of shell composed of long prismatic cells, nearly parallel with surface and mingled with dark cells as in *Pinna*; inner layer also cellular.

Dall¹⁸ has published a revision of the Solemyidae.

Solemya has been recorded from Paleozoic to Recent (Carboniferous and possibly Silurian to Recent). The genus has been cited from the Eocene of California by Clark & Woodford¹⁹ and it also occurs from upper Oligocene or lower Miocene to Recent in western North America. *Solemya* (*Solemya*) *lomitensis* Olsson²⁰ has been described from the Oligocene of Peru, and Marwick²¹ has recorded the genus from the lower Miocene of New Zealand. It also occurs in the Cenozoic of various other parts of the world.

In *Solemyarina* Iredale²² with the type *S. velesiana* Iredale "The median rib is not curved, but is angulated posteriorly, while the anterior portion of the ligament is small and linear and the posterior portion is small and sub-linear, the posterior muscle scar free" (Iredale, 1939).

Zesolemya was proposed by Iredale²³ for the New Zealand species *Solemya parkinsonii* Gray.

¹⁸ Dall, W. H., A Revision of the Solenomyacidae. *Nautilus*, Vol. 22, no. 1, May, 1908, pp. 1-2. See also, Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, pp. 361-366.

¹⁹ *Solemya* sp., Clark & Woodford, *Univ. Calif. Publ. Bull. Dept. Geol. Sci.*, Vol. 17, no. 2, December 31, 1927, p. 85, pl. 14, fig. 1. Univ. Calif. Loc. 3162. North side of Deer Valley, north of Mt. Diablo, Mt. Diablo Quadrangle, California. Meganos formation; Eocene.

²⁰ *Solemya* (*Solemya*) *lomitensis* Olsson, *Bull. Amer. Paleol.*, Vol. 17, no. 68, June 5, 1931, p. 127 (31), pl. 15 (3), fig. 5. "Lomitos," Peru; Oligocene.

²¹ Marwick, J., *Geol. Surv. New Zealand, Palaeo. Bull.* No. 18, 1931, p. 48, pl. 1, fig. 1.

²² *Solemyarina* Iredale, *Rec. Austral. Mus.*, Vol. 18, no. 4, June 29, 1931, pp. 202, 231. "I introduce *Solemyarina* for these small species, designating *velesiana* as type." Sydney, Australia. —Iredale, *Brit. Mus. (Nat. Hist.) Great Barrier Reef Exped. 1928-29. Sci. Repts.*, Vol. 5, no. 6, Moll. Pt. 1, 1939, p. 232 "Orthotype: *Solemya velesiana* Iredale."

²³ *Zesolemya* Iredale, *Brit. Mus. (Nat. Hist.) Great Barrier Reef Exped. 1928-29. Sci. Repts.*, Vol. 5, no. 6, Moll. pt. 1, 1939, p. 233.

KEY TO THE SPECIES OF *Solemya*.

- A. Ligament internal (subgenus) *Petrasma*
 - a. Anterior end with 8 or 9 obscure rays *panamensis*
 - aa. Anterior end with fine radial striae only *valvula*
- B. Ligament external (subgenus) *Acharax*
 - a. Dorsal margin with a heavy callous *patagonica*
 - aa. Dorsal margin without accessory callous
 - b. Entire surface with subequally spaced radiating rays *johnsoni*
 - bb. Surface with central area smooth or with obsolete rays
 - c. Posterior end evenly rounded *agassizii*
 - cc. Posterior end meeting hinge line and basal margin at rounded right angles *macroductyla*

Subgenus *Acharax* Dall.

Acharax Dall, *Nautilus*, Vol. 22, no. 1, May, 1908, p. 2. "Type *S. johnsoni* Dall." —Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 364.

Type (by original designation): *Solemya johnsoni* Dall.

Ligament opisthodontic, wholly external, visible internally only where it crosses the gap between the margins of the valves. Nymphs without props (Dall).

Acharax has been recorded from Oligocene to Recent.

Solemya (Acharax) agassizii Dall.

S[olemya]. agassizii Dall, *Nautilus*, Vol. 22, no. 1, May, 1908, p. 2. "Off Tillamook Bay, Oregon, south to Aguja Point, Peru, in 1036-1800 fathoms."

Solemya (Acharax) agassizii Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 365, pl. 16, fig. 10. U. S. S. Albatross station 3360, "Gulf of Panama, in 1672 fathoms, sand, bottom temperature 36°.4 F." Also at other stations from 1588, 1740, 1772, and 1793 fathoms; off Aguja Point, Peru, in 1036 fathoms; range; Gulf of California to off Aguja Point, Peru. —Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama.—I. S. Oldroyd, *Stanford Univ., Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 9, pl. 40, fig. 11 (under subgenus *Acharax*). Original records cited.

Acharax agassizii Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 9. Tillamook, Oregon, to Point Aguja, Peru.

Type Locality: Gulf of Panama, in 1672 fathoms. Type No. 106,885 U. S. Nat. Mus.

Range: Off Tillamook, Oregon, to Aguja Point, Peru, in 1036 to 1800 fathoms.

The shell of *Solemya agassizii* is ornamented by about five or six anterior radial channels rather than from nine to twelve on *S. johnsoni*. *S. agassizii* differs from *S. macroductyla* Mabile & Rochebrune, a more southern species, in the presence of a smooth middle area on the valves, as well as the proportionately shorter posterior end, and much larger size. *S. grandis* Verrill & Bush²⁴, an Atlantic species, has a shorter and wider shell.

Solemya (Acharax) dalli Clark²⁵ from the lower Miocene or upper Oligo-

²⁴ *Solemya grandis* Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, [No. 1139.], 1898, p. 885, pl. 86, figs. 1 and 2. "Two good specimens and some fragments, at four stations, between N. lat. 39° 58' 30", W. long. 70° 30', and N. lat. 37° 24', W. long. 74° 17', in 300 to 1,600 fathoms, 1880-1884."

²⁵ *Solemya dalli* Clark, *Univ. Calif. Publ. Bull. Dept. Geol. Sci.*, Vol. 15, no. 4, January 5, 1925, p. 73, pl. 8, fig. 2. L.S.J.U. Loc. NF. 120. "Shales outcropping in sea cliffs west of West Twin River for distance of ¼ mile, Twin, Washington." —Tegland, *Univ. Calif. Publ. Bull. Dept. Geol. Sci.*, Vol. 23, no. 3, October 11, 1933, p. 103, pl. 4, figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Type locality. Also from Restoration Point, Blakeley formation, near Seattle, Washington. Upper Oligocene.

cene of Washington is a somewhat similar species and *Solemya tokunagai* Yokoyama²⁶ and *S. yessoensis* Kanehara²⁷, from the Tertiary of Japan, are members of the same group.

Solemya (Acharax) belenensis Olsson²⁸ has been described from the Oligocene of Peru.

***Solemya (Acharax) johnsoni* Dall.**

Solemya johnsoni Dall, *Proc. U. S. Nat. Mus.*, Vol. 14, 1891, p. 189. "U. S. steamer *Albatross*, station 3010, off coast of Lower California, in 1,005 fathoms." —Dall, *Proc. U. S. Nat. Mus.*, Vol. 17, 1894, p. 712, pl. 25, fig. 1. Coast of Ecuador in 1,740 fathoms; Gulf of Panama, in 1,672-1,493 fathoms; Gulf of California in 1,000-1,588 fathoms; Straits of Fuca, in deep water. —Keep, *West Amer. Shells* (The Whitaker & Ray Co.,) San Francisco, 1904, p. 19, fig. 8. Deep water as far north as Puget Sound. —Dall, *Nautilus*, Vol. 22, no. 1, 1908, p. 2. Puget Sound to Panama Bay in 60 to 1740 fathoms. —Keep, *West Coast Shells*, (The Whitaker & Ray-Wiggin Co.) San Francisco, 1911, p. 24, fig. 10. Same locality as cited 1904. Edit. by Baily, 1935, p. 45, fig. 20 (as *Solemya (Acharax) johnsoni*). Oregon to Panama. —Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama. —I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 9, pl. 14, fig. 1 (under subgenus *Acharax*). Type locality cited. Range: Oregon to Panama.

Solenya [Typ. error] *johnsoni* [Dall], Pilsbry, *Nautilus*, Vol. 5, no. 4, August, 1891, p. 47.

Solenomya johnsoni Dall, Rogers, *The Shell Book*, (Doubleday, Page & Co., Garden City, New York), 1913, p. 368. Puget Sound Southward.

Acharax johnsoni Dall, Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 9 (under genus *Solemya*). Oregon to Panama.

Type Locality: Off the coast of Lower California, in 1,005 fathoms.

Range: Puget Sound to Panama.

There are nine to twelve anterior radial channels on the shell of *Solemya johnsoni*, while there are only five or six such channels on the similar *S. agassizii*.

***Solemya (Acharax) macrodactyla* Mabilie & Rochebrune.**

Solemya macrodactyla Mabilie & Rochebrune, *Miss. Sci. Cap Horn*, Vol. 6, Zool., pt. 2, 1891, p. H109, pl. 8, fig. 4. "*Hab. Baie Orange*." —Dall, *Nautilus*, Vol. 22, no. 1, May, 1908, p. 2. —Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, 1908, p. 364. Orange Harbor, Patagonia, north to Chiloë Island, southwest Chile, in 20 to 369 fathoms.

Type Locality: Orange Harbor, Patagonia.

Range: Orange Harbor and north to Chiloë Island, southwest Chile, in 20 to 369 fathoms.

This southern species, *Solemya macrodactyla*, bears a resemblance to *Solemya agassizii* which occurs farther north, but the posterior end is less rounded than it is in that species. Mabilie & Rochebrune compared *S. mac-*

²⁶ *Solemya tokunagai* Yokoyama, *Jour. Coll. Sci. Imp. Univ. Tokyo*, Vol. 45, Article 5, March 21, 1925, p. 31, pl. 6, figs. 1, 2, 3. "Shiogu in Tatsuta; Tsuchibashi in Kadono; Enamura Quarry." Pliocene. —Kanehara, *Jap. Jour. Geol. & Geogr.*, Vol. 14, nos. 3 & 4, 1937, p. 156, pl. 15, figs. 10, 11 (as *Solemya (Acharax) tokunagai*). "Near Mōrae, Atsuta-gun, Ishikari." Oiwake Series; upper Miocene to Pliocene.

²⁷ *Solemya (Acharax) yessoensis* Kanehara, *Jap. Jour. Geol. & Geogr.*, Vol. 14, nos. 3 & 4, October, 1937, p. 155, pl. 15, fig. 12. "Near Mōrai, Atsuta-gun, Ishikari." Oiwake Series; upper Miocene to Pliocene.

²⁸ *Solemya (Acharax) belenensis* Olsson, *Bull. Amer. Paleont.*, Vol. 17, no. 68, June 5, 1931, p. 127 (31), pl. 15 (3), fig. 7. "Heath formation, Lobos, Pajarabobo." Peru; Oligocene.

rodactyla to *S. borealis* Totten which occurs from Halifax, Nova Scotia, to Connecticut, and to *S. parkinsonii* Gray²⁹ of New Zealand. Dall has pointed out that *Solemya macrodactyla* may ultimately be relegated to the synonymy of *S. patagonica* E. A. Smith.

***Solemya (Acharax) patagonica* E. A. Smith.**

Solemya patagonica E. A. Smith, Sci. Res. Voy. Challenger, Zool., Vol. 13, 1885, pp. 24, 208, pl. 11, figs. 1, 1a. "Habitat. ——— Station 311, off west coast of South Patagonia, in 245 fathoms." ——— Dall, *Nautilus*, Vol. 22, no. 1, May, 1908, p. 2. ——— Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 364. West coast of Patagonia.

Type Locality: Off west coast of Chile, in 245 fathoms.

Range: West coast of Chile.

At the time of description of *Solemya patagonica*, E. A. Smith compared the species to *S. parkinsonii* Gray of New Zealand. Dall considered it likely that *S. macrodactyla* Mabile & Rochebrune might be relegated to the synonymy of *S. patagonica*, but stated that the type of *S. patagonica* appeared to be abnormally callous dorsally.

E. A. Smith (*Ann. & Mag. Nat. Hist.*, Ser. 7, vol. 18, October, 1906, p. 253) has cited *S. patagonica* from off India, and Melvill & Standen (*Proc. Zool. Soc. London*, November 13, 1906, p. 793) have cited it from the Gulf of Oman in the Arabian Sea. We have not seen specimens from that region.

Subgenus ***Petrasma*** Dall.

Petrasma Dall, *Nautilus*, Vol. 22, no. 1, May, 1908, p. 2. "Type *S. borealis* Totten." ——— Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 363.

Type (by original designation): *Solemya borealis* Totten. [*Amer. Jour. Sci.*, Ser. 2, Vol. 26, July, 1834, p. 366, pl. [unnumbered], fig. 1. h, i. "Inhabits the coast of Rhode Island." Also illustrated by M. Smith, East Coast Mar. Shells (Edwards Bros., Ann Arbor, Michigan), 1937, p. 25, fig. 29a. Nova Scotia to Connecticut].

Ligament internal but not exposed internally in front of the chondrophore.

Solemya (Petrasma) panamensis Dall.

S[olemya]. panamensis Dall, *Nautilus*, Vol. 22, no. 1, May, 1908, p. 2. "extends from off Santa Barbara, Cal., to Panama Bay."

Solemya (Petrasma) panamensis Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 366. "U. S. S. 'Albatross,' station 2799, Panama Bay, in 29½ fathoms, mud." Also off Santa Barbara, California, in 68 fathoms.

Solemya panamensis Dall, Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama. ——— I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 10, pl. 9, fig. 4. Original record cited. ——— Pilsbry & Lowe, *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 84, 1932, p. 141. "On mud flats at extreme tide, rare. La Paz." ——— Lowe, *Trans. San Diego Soc. Nat. Hist.*, Vol. 8, no. 6, 1935, p. 27. Punta Penasco, Sonora, Mexico, dredged in 10 fathoms. ——— Strong, *Proc. Calif. Acad. Sci.*, Ser. 4, Vol. 23, no. 12, 1937, p. 192. San Martin Island, Lower California, Mexico.

²⁹*Solemya parkinsonii* Gray, Voy. Erebus & Terror, 1874, p. 6, pl. 3, fig. 1 ——— Suter, *Man. New Zealand Moll.* (Wellington, New Zealand), 1913, p. 830, pl. 58, fig. 1. Throughout New Zealand, in mud about 6 inches below the surface; Kermadec Islands; Milford Sound, in 100-120 fathoms.

Petrasma panamensis Dall, U. S. Nat. Mus., Bull. 112, 1921, p. 9. Santa Barbara, California, to Panama.

Type Locality: Panama Bay, 29½ fathoms. Type No. 110,678 U. S. Nat. Mus.

Range: Santa Barbara, California, to Panama.

This is more expanded in front and less sharply truncate in front than *S. agassizii* of the same length, and they may be separated at once by the difference in the hinges. *S. valvulus* Carpenter is a much smaller species and has no anterior prop to the chondrophore (Dall).

***Solemya (Petrasma) valvulus* Carpenter.**

Solemya valvulus Carpenter, Ann. & Mag. Nat. Hist., Ser. 3, Vol. 13, April, 1864, p. 311. Cape St. Lucas. Reprint in *Smithson. Misc. Coll.*, No. 252, 1872, p. 210. —Carpenter, Rept. Brit. Assoc. Adv. Sci. for 1863 (issued August, 1864), p. 618. Reprint in *Smithson. Misc. Coll.*, No. 252, 1872, p. 104. —Dall, *Nautilus*, Vol. 22, no. 1, May, 1908, p. 2. San Pedro, California, to the Gulf of California. —Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 364. San Pedro, California, to the Gulf of California. —I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 11, pl. 40, fig. 10 (under subgenus *Petrasma*). Type locality cited. Range: San Pedro, California, to the Gulf of California. —Lowe, *Trans. San Diego Soc. Nat. Hist.*, Vol. 8, no. 6, 1935, p. 27. Punta Penasco, Sonora, Mexico, dredged in 10 fathoms.

Solemya (Petrasma) valvulus Carpenter, Lamy, *Journ. de Conchyl.*, Vol. 57, no. 3, 1909, p. 208. Gulf of California.

Petrasma valvulus Carpenter, Dall, U. S. Nat. Mus., Bull. 112, 1921, p. 9. San Pedro, California, to the Gulf of California.

Type Locality: Cape San Lucas, Lower California.

Range: San Pedro, California, to Punta Penasco, Sonora, Mexico.

The shell of *Solemya valvulus* is small, thin, transparent and attains a length of about 20 mm. It is ornamented by radial slender brownish lines which are finely striate posteriorly, distantly spaced on the medial portion of the shell, and short, broad, and bifurcate anteriorly. The chondrophore is without props.

Superfamily Nuculacea.

Family Nuculidae.

The family Nuculidae is an ancient one and has representatives in the Paleozoic. *Praenucula* Pfab³⁰ assigned to this family has been described from the Silurian of Bohemia. In the Nuculidae the pallial impression is entire, due to the lack of development of siphons. The shells are entirely closed, not gaping, and the inner shell-layer is pearly. The family occurs in both shallow and deep water. A few occur in tropical waters but most of the species occur in temperate and boreal waters.

Two papers by Schenck³¹ on the classification of nuclid pelecypods may be consulted regarding the nomenclature of members of this family. Dr. Schenck has kindly examined a number of specimens of *Nucula* and *Nuculana* in the present collection and has furnished us notes on certain of the species.

³⁰*Praenucula* Pfab, *Palaeontogr.*, Bd. 80, Abt. A, Lief. 4-6, April, 1934, p. 234. "Typus des Genus: *P. dispar expansa* n. var." p. 235, pl. 3, figs. 10, 11, 15a, 15b. Osek.

³¹Schenck, H. G. Classification of Nuclid Pelecypods. *Bull. Mus. Roy. d'Hist. Nat. Belgique*, Vol. 10, no. 20, June, 1934, 78 pp., 6 pls. —Schenck, H. G. Revised Nomenclature for some Nuclid Pelecypods. *Jour. Paleol.*, Vol. 13, no. 1, pp. 21-41, 4 pls., January, 1939.

Genus *Nucula* Lamarck.

Nucula Lamarck, *Mem. Soc. Hist. Nat. Paris*, Vol. 1, 1799, p. 87. Sole species: *Arca nucleus* Linnaeus. ————Schenck, *Bull. Mus. Roy. d'Hist. Nat. Belg.*, Vol. 10, no. 20, 1934, p. 18, pl. 1, fig. 8; pl. 3, fig. 2; pl. 4, figs. 4, 4a, 4b; pl. 5, figs. 1, 1a. "(Type by monotypy: *Arca nucleus* Linné.)"

Type (by monotypy): *Arca nucleus* Linnaeus. [Syst. Nat., Ed. 10, 1758, p. 695. "*Habitat in Europa.*" Illustrated by Schenck, *Bull. Mus. Roy. d'Hist. Nat. Belg.*, Vol. 10, no. 20, 1934, p. 18, pl. 1, fig. 8; pl. 3, fig. 2; pl. 4, figs. 4, 4a, 4b; pl. 5, figs. 1, 1a. ————Schenck, *Proc. Malacol. Soc. London*, Vol. 21, pt. 4, March, 1935, fig. 1 (p. 260)].

Shell closed, not gaping; profile ovate-trigonal; a "pouting" of the escutcheonal area, which the radial ribs do not cross; beaks opisthogyrate, appressed; prodissoconch unornamented; radial ribs faint, low, wide and flat, often difficult to see on the middle part of the shell, but they are more distinct near the ventral margin where they form the "pectinate margin"; interspaces narrow, about one-tenth the width of the ribs; interior nacreous; pallial line simple; two subequal adductor muscle scars and additional muscle scars; longer (anterior) row of teeth arched, with $16 \pm$ to $24 \pm$ teeth; the shorter (posterior) row straight with $7 \pm$ to $11 \pm$; axis of chondophore forms an arc of a circle of which the arcuate dorsal margin is a part (Schenck).

KEY TO THE SPECIES OF *Nucula*⁸².

- A. Outer surface smooth
 - a. Periostracum olive
 - b. Periostracum dark olive
 - c. Length less than 10 mm
 - d. Shape subcordate, umbos weak, length 8 mm., height 4 mm. *tenuis*
 - dd. Shape subtrigonal, umbos prominent, length 6 mm., height 5 mm. *linki*
 - cc. Length over 20 mm., solid, thick *panamina*
 - bb. Periostracum pale olive
 - e. Length less than 10 mm., shape, ovate *colombiana*
 - ee. Length 14-21 mm. *saratieri*
 - aa. Periostracum greenish or black
 - f. Periostracum greenish
 - g. Anterior hinge teeth 8, posterior 18 *cardara*
 - gg. Anterior hinge teeth 5, posterior 11 *grayi*
 - ff. Periostracum nearly black *agujana*
- B. Outer surface sculptured
 - a. Concentric sculpture only
 - b. Length less than 10 mm. *pisum*
 - bb. Length over 20 mm. *tanneri*
 - aa. Radial sculpture present
 - c. Radial sculpture faint
 - d. Length less than 5 mm.
 - e. Anterior teeth less than 15

⁸² In the case of species which are not illustrated and which we have not seen, the key is based upon descriptions.

KEY TO THE SPECIES OF *Nucula* (continued):

- f. Sculpture definitely reticulate, concentric strong, anterior teeth 9, posterior 5 *schencki*
- ff. Sculpture not reticulate, concentric weak, anterior teeth 10, posterior 6 *chrysocoma*
- ee. Anterior teeth 17, posterior 9 *paytensis*
- dd. Length over 10 mm.
 - g. Anterior hinge teeth 6, posterior 10 *taeniolata*
 - gg. Anterior hinge teeth 7, posterior 15-17 *pigafettae*
- cc. Radial sculpture strong
 - h. Length less than 10 mm.
 - i. Concentric sculpture heavier, regular rugae *exigua*
 - ii. Concentric sculpture fine, irregular *declivis*
 - hh. Length over 30 mm. *iphigenia*

***Nucula (Nucula) declivis* Hinds.**

Plate I, Figures 1, 2, 3, 6, 7.

Nucula declivis Hinds, *Proc. Zool. Soc. London*, December, 1843, p. 98. "Hab.?" —Hinds, *Zool. Voy. Sulphur*, Moll. Pt. 3, 1844 (January, 1845, on cover of Pt. 3), p. 63, pl. 18, fig. 8. "Inhab.?" —Hanley, *Thes. Conch.*, Vol. 3, 1860, *Nucula*, p. 154, pl. 230 (*Nuculidae*, pl. 5), fig. 147. "Hab.?" —Sowerby, *Conch. Icon.*, Vol. 18, *Nucula*, October, 1870, sp. 31, pl. 4, fig. 31. "Hab.?" —Dall, *Proc. U. S. Nat. Mus.*, Vol. 31, 1909, p. 250. "Panama to Magellan Straits." —Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama. —Lowe, *Trans. San Diego Soc. Nat. Hist.*, Vol. 8, no. 6, 1935, p. 27. Punta Penasco, Sonora, Mexico. —Strong & Hertlein, *Allan Hancock Pacific Exped. (Univ. South. Calif.)*, Vol. 2, no. 12, 1939, p. 183. Bahia Honda, and off Taboga Island, Panama.

Type Locality: Original locality not known. Type locality here designated as off Taboga Island, Panama, in 3-9 fathoms.

Range: Punta Penasco, Sonora, Mexico, to Panama. [?] Panama to Magellan Straits (Dall).

Collecting Stations: Mexico: Santa Inez Bay, Gulf of California (145-D-1,-3). 4-15 fathoms, sand; Manzanillo Bay (184-D-2). 30 fathoms, gravelly sand bottom; Nicaragua: Corinto (200-D-19 and beach). 12-13 fathoms, mangrove leaves; Costa Rica: (203-D-1,-3). 12-15 fathoms, sand and shelly mud bottom.

This species has a small, smooth, oblique shell ornamented by very fine radial striations. In the original description it is stated that the ventral margin is crenulate, and that the species is "a still more oblique shell than *N. pisum*, to which it is closely allied." From the original illustrations alone it would be difficult to separate *N. declivis* from *N. pisum* Sowerby although Sowerby's species appears to be less oblique. *N. pisum* was originally described from Valparaíso, Chile. Hanley and Dall have considered *N. semiornata* d'Orbigny³³ to be synonymous with *N. pisum*. Specimens of *N. declivis* from the Gulf of California resemble, in general features, *N. crenulata* Adams³⁴ from Florida.

³³ *Nucula semi-ornata* d'Orbigny, *Voy. Amér. Mérid.*, Vol. 5, 1846, p. 624, pl. 84, figs. 27, 28, 29. "Nous l'avons recueillie dans la baie de San Blas, au nord de la Patagonie, où elle vit au niveau des plus basses marées. Elle y est très-rare. M. Darwin l'a rencontrée fossile à la baie Blanche."

³⁴ *Nucula crenulata* A. Adams, *Proc. Zool. Soc. London*, 1856, p. 52. "Hab. Guadeloupe Mus. Cuming." —Hanley *Thes. Conch.*, Vol. 3, 1860, p. 154, pl. 229, (*Nuculidae*, pl. 4), figs. 134, 135. "Guadeloupe." —Sowerby, *Conch. Icon.*, Vol. 18, *Nucula*, October, 1870, sp. 25, pl. 4, fig. 25. "Hab. Guadeloupe."

***Nucula (Nucula) exigua* Sowerby.**

Plate I, Figures 4, 5.

Nucula exigua Sowerby, *Proc. Zool. Soc. London* for 1832 (issued March 13, 1833), p. 198. "Hab. ad Columbiam Occidentalem (Bay of Caraccas)." [Ecuador Lat. 0° 35'S.] "A single specimen found in sandy mud at nine fathoms depth." —Sowerby, *Conch. Illustr.*, 1833, *Nuculae*, p. 6, pl. 16, figs. 24, 24*. "Bay of Caraccas." —Müller, *Synop. Test. Viv.*, 1836, p. 192. Type locality cited. —Hanley, *Cat. Rec. Bivalve Shells*, p. 172, 1843, p. 376, ?1856. Suppl. pl. 20, fig. 13, 1856. W. Colombia. —d'Orbigny, *Voy. Amér. Mérid.*, Vol. 5, 1846, p. 625. Original locality cited. —C. B. Adams, *Ann. Lyceum Nat. Hist. New York*, Vol. 5, 1852, p. 479. Panama. Also earlier records cited. —Carpenter, *Cat. Mazatlan Shells*, February, 1856, p. 145. (as *Nucula ? exigua*). Mazatlan, Mexico. Also earlier records cited. —Carpenter, *Rept. Brit. Assoc. Adv. Sci. for 1856* (issued 1857), pp. 249, 277, 311. Gulf of California; Central America; Panama; Bay of Caraccas, Ecuador. —Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 154, pl. 229, (*Nuculidae*, pl. 4), fig. 136. "Bay of Caracas. W. Columbia." —Carpenter, *Proc. Zool. Soc. London*, 1863, p. 364. Reprint in *Smithson. Misc. Coll.*, No. 252, 1812, p. 200. C. B. Adams' record cited. —Sowerby, *Conch. Icon.*, Vol. 18, *Nucula*, October, 1870, sp. 26, pl. 4, fig. 26. "Hab. West Columbia." —Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, 1908, p. 370. Bay of Panama (Cuming); off Acapulco, Mexico, in 660 fathoms; near the Galapagos Islands, in 812 fathoms; off Aguja Point, Peru, in 1036 fathoms; west coast of Patagonia, in 122 and 194 fathoms. —Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 250. Acapulco, Mexico, to Ecuador and to the Magellanic region. —Zetek, *Rev. Nueva*, Nos. 1 and 2, 1918, p. 51. Zoogeographical province of Panama. —Olsson, *Nautilus*, Vol. 37, no. 4, 1924, p. 126. Salinas, Ecuador. Common. —E. K. Jordan, *Contrib. Dept. Geol. Stanford Univ.*, Vol. 1, no. 4, 1936, p. 112. Magdalena Bay, Lower California, Pleistocene.

Nucula (Nucula) exigua Sowerby, Schenck, *Jour. Paleo.*, Vol. 13, no. 1, 1939, p. 36, pl. 6, figs. 1-8, 11. Type loc. cited. Also western North America.

Type Locality: Bay of Caraccas, Ecuador, in 9 fathoms, in sandy mud. Type in Brit. Mus. (Nat. Hist.).

Range: San Bartolome Bay [Turtle Bay], Lower California, and Gulf of California to Ecuador. [?] Magellanic region (Dall).

Collecting Station: Nicaragua: Corinto (200-D-19). 12-13 fathoms, mangrove leaves.

The shell of *Nucula exigua* is ornamented by concentric and radial ornamentation but the concentric is much the stronger. It is a small shell averaging not over 5 mm. in length. A strongly projecting lunular area just under the beaks appears to be a characteristic feature of the species. These differences are well shown on photographs of the type of *N. exigua* shown to us by H. G. Schenck.

Some authors have considered *N. exigua* to be identical with *N. suprastrata* Carpenter (in Arnold) but Schenck has given reasons for considering them to be distinct species. The radial ribbing on *N. suprastrata* is not well developed and usually is present only near the ventral margin. The lunule and escutcheon is more deeply impressed on *N. suprastrata* and it is a larger shell averaging 5.5 to 6 mm. in length. *Nucula cahuitensis* Olsson³⁵ from the Miocene of Costa Rica was compared to *N. exigua* by Olsson.

Nucula paytensis A. Adams, bears considerable similarity to *N. exigua*. Photographs of the type of the species described by Adams show a more rounded outline and broader projecting lunular area but we are not certain whether these differences are constant characters which can be used to separate the two species.

³⁵ *Nucula (Nucula) suprastrata* Carpenter in Arnold, *Mem. Calif. Acad. Sci.*, Vol. 3, 1903, p. 86, pl. 18, fig. 6. "Upper San Pedro series, Los Cerritos" Upper Pleistocene. Also at Spanish Bight, San Diego, California, upper Pleistocene. Rare in lower San Pedro of Deadman Island, lower Pleistocene, and in the upper San Pedro Series of San Pedro, California, upper Pleistocene. —Schenck, *Jour. Paleo.*, Vol. 13, no. 1, 1939, p. 36, pl. 6, figs. 9, 10, 12, 13. Various localities in the Pleistocene of southern California.

³⁶ *Nucula cahuitensis* Olsson, *Bull. Amer. Paleo.*, Vol. 9, Bull. No. 39, June 21, 1922, p. 343 (171), pl. 21 (18), figs. 21-24. "Gatun Stage: Zone G, Saury Creek," Costa Rica. Miocene.

Subgenus **Ennucula** Iredale.

Ennucula Iredale, *Rec. Australian Mus.*, Vol. 18, no. 4, June 29, 1931, pp. 202, 231. "Type *Nucula obliqua* Lamarck. —Schenck, *Bull. Mus. Roy. d'Hist. Nat. Belg.*, Vol. 10, no. 20, 1934, p. 37, pl. 3, figs. 4, 4a, 4b; pl. 4, figs. 3, 3a, 3b. Type: *Nucula obliqua* Lamarck. —Cotton & Godfrey, *Moll. South Australia*, Pt. 1. Handbook of Flora and Fauna of South Australia, issued by South Australian Branch of Brit. Sci. Guild, Adelaide, 1938, p. 40. "Genotype —*E. obliqua* Lamarck." —Iredale, *Brit. Mus. (Nat. Hist.) Great Barrier Reef Exped.* 1928-29 Sci. Repts. Vol. 5, no. 6, Moll., pt. 1, 1939, p. 235. Orthotype: *Nucula obliqua* Lamarck.

Type (by original designation): *Nucula obliqua* Lamarck. [Anim. s. Vert., Vol. 6, 1819, p. 59. "Habite les mers australes, au cap aux Huitres." —Illustrated by Schenck, *Bull. Mus. Roy. d'Hist. Nat. Belg.*, Vol. 10, no. 20, 1934, p. 37, pl. 3, figs. 4, 4a, 4b; pl. 4, figs. 3, 3a, 3b. "Cap aux Huitres, Nouvelle Hollande."]

The type species of *Nucula* is *nucleus* Linné, a European species which differs appreciably from antipodean shells so classed, the latter having a notably oblique chondrophore, above which the teeth become much smaller, and the angle of opposition of the two rows of teeth is scarcely marked; further, the edge of the European shell is strongly denticulate, whereas ours is practically smooth (Iredale).

***Nucula (Ennucula) tenuis* Montagu.**

Arca tenuis Montagu, *Test. Brit.*, Suppl., 1808, p. 56, pl. 29, fig. 1. "on the shore near Dunbar," England.

Nucula tenuis Montagu, Forbes & Hanley, *Hist. Brit. Moll.*, Vol. 2, 1853, p. 223, pl. 47, fig. 6; and (animal) pl. P, fig. 5. England and North Atlantic, Massachusetts. Also Pliocene. —Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 161, pl. 229 (*Nuculidae*, pl. 4), figs. 140, 141. Britain, W. Europe. —Sowerby, *Conch. Icon.*, Vol. 18, *Nucula*, October, 1870, sp. 20, pl. 3, fig. 20. "*Hab. Britain, Europe.*" —I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, no. 1, 1924, p. 13, pl. 5, fig. 12; pl. 37, fig. 4. Point Barrow, Alaska, to Coronado Islands, California. Circumboreal. Pliocene at San Pedro and San Diego, California. —Antevs, *För. Geol. Fören. i Stockholm*, Bd. 50, Heft 4, 1928, p. 493.

Nucula (Nucula) tenuis Montagu, Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 111. Earlier records cited. "Miocene" [Pliocene] of St. Paul Island, and Nushagak Island, Alaska (Dall), and Recent. Circumboreal.

Nucula (Ennucula) tenuis Montagu, Schenck, *Jour. Paleol.*, Vol. 13, no. 1, January, 1939, p. 33, pl. 8, figs. 1-4, 9, 12, 14, 15. Earlier records cited.

Not *Pronucula tenuis* Powell, *Rec. Canterbury Mus.*, Vol. 3, no. 2, December 14, 1927, p. 119, pl. 22, figs. 1, 2. Southwest of Otago, New Zealand, in 100 fathoms.

Type Locality: Near Dunbar, England, on shore.

Range: Northern Europe. Northeastern North America. Circumboreal. Point Barrow, Alaska, to Cedros Island, Lower California.

Collecting Station: Mexico: East of Cedros Island (126-D-12). 45 fathoms, crushed shell and mud bottom.

One specimen of *Nucula tenuis* was dredged in Lat. 28° 20' N., Long. 115° 10' 30" W., one mile east of Cedros Island, Lower California. Heath³⁷ has recently studied the soft parts of this species.

This appears to be a wide-ranging form. According to Schenck some of the specimens dredged off British Columbia agree exactly with specimens of the species from the North Sea. Schenck has placed *Nucula tenuis* in the subgenus *Ennucula* Iredale. The bathymetric range of the species given by Antevs is 2 to 1,200 meters.

³⁷ Heath, H., *Mem. Mus. Roy. d'Hist. Nat. Belgique*, Ser. 2, Fasc. 10, 1937, pp. 4, 9, etc., pl. 3, figs. 19, 20, 21, 22, 26; pl. 4, figs. 31, 33, 34; pl. 5, fig. 44; pl. 9, fig. 81. Behring Sea, in 36 fathoms.

***Nucula (Ennucula) cardara* Dall.**

Nucula cardara Dall, *Proc. U. S. Nat. Mus.*, Vol. 52, December 27, 1916, p. 394. "Station 5673, in 1090 fathoms, mud, off San Diego, California." —Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 10. Monterey, California, to Lower California, in deep water. —I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 12. Type locality and range same as cited by Dall. —Keen, *Check List West North Amer. Mar. Moll.* (Stanford Univ. Press), 1937, p. 23. Lat. 30°-37° N.

Nucula (Ennucula) cardara Dall, Schenck, *Jour. Paleo.*, Vol. 13, no. 1, January, 1939, p. 34, pl. 5, figs. 12, 14, 18, 21. Type locality cited.

Type Locality: Off San Diego, California, in 1090 fathoms, mud. Type No. 265905 U. S. Nat. Mus.

Range: Monterey, California, to Lat. 30' N., Lower California, in deep water.

Shell elongate-ovate, thin, polished, light olive green in color; hinge with 8 anterior and 18 posterior teeth; margins of valves smooth. Length, 16 mm.; height, 11.5 mm.; diameter, 8 mm.

***Nucula (Ennucula?) linki* Dall.**

Nucula linki Dall, *Proc. U. S. Nat. Mus.*, Vol. 52, December 27, 1916, p. 394. "Station 3034, 24 fathoms, mud; off Point Fermin, Lower California." —Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 10. Queen Charlotte Sound to Guaymas, Mexico. —I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 12. Type locality and range same as cited by Dall. —Keen, *Check List West North Amer. Mar. Moll.* (Stanford Univ. Press), 1937, p. 23, Lat. 23°-55° N.

Nucula (Ennucula?) linki Dall, Schenck, *Jour. Paleo.*, Vol. 13, no. 1, January, 1939, p. 33, pl. 5, figs. 2, 6, 11, 15. Type locality cited.

Type Locality: Off Point Fermin, California, in 24 fathoms, mud. [According to Schenck, not from off Point Fermin, Lower California, as originally cited by Dall]. Type No. 107649 U. S. Nat. Mus.

Range: Queen Charlotte Sound, British Columbia, to Guaymas, Sonora, Mexico.

Shell small, inflated, very inequilateral, subtriangular and of a dark olive color; hinge with six anterior and eleven posterior teeth; valve margins entire. Length, 6 mm.; height, 5 mm.; diameter, 3.6 mm.

Subgenus *Nuculopsis* Woodring.

Nuculopsis Woodring, *Carnegie Inst. Washington, Publ.* No. 366, May, 1925, p. 14. [Cited in caption only. ? Typ. error.].

Nuculopsis Woodring, *Carnegie Inst. Washington, Publ.* No. 366, May, 1925, p. 14. "Type. —*Nucula (Nuculopsis) hilli* new species." —Schenck, *Bull. Mus. Roy. d'Hist. Nat. Belg.*, Vol. 10, no. 20, June, 1934, p. 33. Type: *Nucula hilli* Woodring.

Not *Nuculopsis* Girty, *Ann. New York Acad. Sci.*, Vol. 21, 1911, p. 133. "Type species, *Nucula ventricosa* Hall." Pennsylvanian series.

Not *Nuculopsis* Rollier. *Abh. Schweiz. Paläont. Gesell.*, Vol. 38, Part 2, 1912, p. 64. Renamed *Isoleda* by Rollier, *Rev. Crit. Paléozool.*, Vol. 27, no. 1, January, 1923, p. 67. "(G.-T. *Nuc. Palmae* Sow.)" Jurassic.

Type (by original designation): *Nucula (Nuculopsis) hilli* Woodring, *Carnegie Inst. Washington, Publ.* No. 366, May, 1925, p. 14, pl. 1, figs. 2 and 3. Bowden, Jamaica, Miocene.

Shell medium-sized, subelliptical, inequilateral; sculpture consisting of strong concentric rugae; chondrophore long, narrow, oblique, deeply excavated; anterior series of teeth more than twice as long as posterior series;

anterior teeth reduced in size toward chondrophore, posterior teeth not reduced; interior of valve subnacreous; lower inner margin of valve smooth (Woodring).

At the present time the subgenus "*Nuculopsis*" is represented by the type species *Nucula hilli*, in the Miocene of Bowden, Jamaica, and by one species, *N. schencki*, in the Recent fauna of western Mexico.

At the time of description of this subgenus Woodring spelled it *Nucolopsis* in the caption but following that on the same page it is consistently spelled "*Nuculopsis*." There is a prior *Nuculopsis* described by Girty and also one by Rollier. Dr. Schenck is working on the family Nuculidae and is of the opinion that *Nucolopsis* may be regarded as a typographical error for *Nuculopsis*. We have used the original spelling used by Woodring but the name may not be valid, and if not it will be rectified in Schenck's forthcoming work on the Nuculidae.

***Nucula (Nuculopsis) schencki* Hertlein & Strong, sp. nov.**

Plate 1, Figures 8, 9, 10.

Shell thin, polished; rather compressed; beaks small; dorsal margin anterior to beaks elevated and broadly rounded; anterior end more acutely rounded; ventral margin and posterior end broadly rounded; sculpture consists of rather closely spaced concentric ribs crossed by faint radiating striae which are weaker on the umbos; lunular area not depressed, area of esutcheon marked only by a very short thin line. Length 2.0 mm., height 1.7 mm., thickness both valves 1.0 mm.

Interior of paratypes reveals a smooth, glossy surface with faint crenulations along the ventral margin corresponding to the exterior striae; chondrophore relatively large, deeply set, elongate, subtriangular, the axis oblique; teeth well developed, about 9 in the anterior series and 5 in the posterior series.

Holotype, from Sta. 195-D-9, dredged in 7 fathoms (12.6 meters) Lat. 15° 44' 28" N., Long. 96° 07' 51" W., Port Guatulco, Mexico, gray sand and crushed shell bottom.

Nucula schencki sp. nov. resembles *Nucula* ("*Nuculopsis*") *hilli* Woodring⁸⁸ described from the Miocene of Jamaica more closely than any Recent west American shell. The more elongate shape, lack of radial striae exteriorly, noncrenulate lower interior margin and greater number of teeth on the Jamaican shell easily separate it from the present species. We have had available photographs of the type specimen of *Nucula hilli* for comparison with our new species. The photographs were furnished by Dr. H. G. Schenck who received them from Dr. Paul Bartsch of the U. S. National Museum.

The new species has been referred to the subgenus *Nuculopsis* because it resembles that group in most of its general characters although it does have very faint crenulations on the interior of the ventral margins.

This species is named for Dr. Hubert G. Schenck of Stanford University in recognition of his work on the Nuculidae.

The subgeneric position of the following species of *Nucula* is uncertain.

***Nucula agujana* Dall.**

Nucula agujana Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 370, pl. 10, figs. 6, 7. U. S. S. *Albatross* station 4654, "twenty-four miles N. 68° W. from Aguja Point, Peru, in 1036 fathoms, mud, bottom temperature 37°.3 F."

⁸⁸ *Nucula (Nuculopsis) hilli* Woodring, *Carnegie Inst. Washington, Publ. No. 366*, May, 1925, p. 14, pl. 1, figs. 2 and 3. Bowden, Jamaica, Miocene.

Type Locality: 24 miles northwest of Aguja Point, Peru, in 1,036 fathoms, mud. Type No. 110,571 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell small, triangular, inequilateral, polished, nearly black with paler olivaceous umbos; hinge with 15 anterior and 9 posterior teeth; margins of the valves smooth. Length, 11 mm.; height, 8 mm.; diameter, 5.75 mm.

***Nucula chrysocoma* Dall.**

Nucula chrysocoma Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 370, pl. 18, figs. 3 and 4. U. S. S. Albatross Station 4656, "off the coast of Peru in S. Lat. 6° 55' and W. Long. 83° 34', in 2,222 fathoms, green mud, bottom temperature 35°.2 F." Also off Manta, Ecuador, in 401 fathoms, and off Acapulco, Mexico, in 660 fathoms.

Type Locality: Off the coast of Peru, Lat. 6° 55' S., Long. 83° 34' W., in 2,222 fathoms, green mud. Type No. 110,572 U. S. Nat. Mus.

Range: Off Acapulco, Mexico, to Peru, in deep water.

Shell small, plump, solid, subtriangular, polished, and of a light yellowish-olive color; sculpture of irregularly spaced impressed concentric lines and fine slightly raised, close-set radial lines; hinge with 10 anterior and 6 posterior teeth; margins of valves entire. Length, 5.0 mm.; height, 4.5 mm.; diameter 3.0 mm.

***Nucula colombiana* Dall.**

Nucula colombiana Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 371. "West coast of Colombia, in Panama Bay at station 2799, in 29½ fathoms." Also in Panama Bay, in 51 fathoms; off Manta, Ecuador, in 401 fathoms; southern Chile, in 122 and in 194 fathoms; off west coast of Patagonia, Lat. 51° 12' S., in 258 fathoms. ———Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 250. Panama to Patagonia.

Type Locality: West coast of Colombia, in Panama Bay, in 29½ fathoms. Type No. 110,686 U. S. Nat. Mus.

Range: Panama to west coast of Patagonia in Lat. 51° 12' S.

Shell small, very inequilateral, ovate, white with a pale olive periorstracum, smooth and brilliantly polished; hinge with 14 anterior and 7 posterior teeth; margins of valves smooth. Length, 4.5 mm.; height, 3.0 mm.; maximum diameter, 2.2 mm.

***Nucula grayi* d'Orbigny.**

Nucula obliqua Lamarck, Sowerby, *Conch. Illustr.*, *Nuculac*, 1833, p. 5, pl. 16, fig. 21. "Valparaiso, Mr. Cuming." ———Hanley, *Cat. Recent Bivalve Shells*, p. 171, 1843, p. 376, 1856?, Suppl. pl. 20, fig. 9, 1856. "Valparaiso, South Seas."

Not *Nucula obliqua* Lamarck, *Hist. Nat. Ann. s. Vert.*, Vol. 6, 1819, p. 59. "Habite les mers australes, au cap aux Huitres."

Nucula grayi d'Orbigny, *Voy. Amér. Mérid.*, Vol. 5, 1846, p. 625. "Cette espèce, la plus grande que nous connaissions dans les mers du Chili, a été recueillie par nous près de Valparaiso, où elle est rare." New name for "*Nucula obliqua*, Gray (non Lamarck)." ———Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 157, pl. 229 (*Nuculidae*, pl. 4), fig. 126. Chili. ———Hupé, *Hist. de Chile, Zool.*, Vol. 8, 1854, p. 304. ———Sowerby, *Conch. Icon.*, Vol. 18, *Nucula*, October, 1870, sp. 13, pl. 2, fig. 13. "*Hab. New Zealand*." [Not New Zealand]. ———Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 250. Valparaiso, Chile.

Type Locality: Valparaiso, Chile.

Range: Known only from the vicinity of the type locality.

Shell thin, oval, much longer than broad, with a polished greenish-olive periostracum; margins entire.

***Nucula iphigenia* Dall.**

Nucula iphigenia Dall, *Proc. U. S. Nat. Mus.*, Vol. 18, April 23, 1896, p. 15. "U. S. Fish Commission station 3396, in 259 fathoms, Gulf of Panama; temperature, 47.4° F." —Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 369, pl. 7, figs. 1 and 4. "Gulf of Panama, in 259 fathoms, hard bottom; temperature, 47.4° F."

Type Locality: Gulf of Panama, in 259 fathoms, hard bottom. Type No. 122,895 U. S. Nat. Mus.

Range: Known only from the type locality.

This fine shell is one of the largest known nucas, and peculiar from its elongated shape and posterior attenuation. The periostracum seems to have been thin, dull, and yellowish (Dall). The margins of the shell are denticulate. The hinge with about 30 anterior and 15 posterior teeth. Length, 35 mm.; height, 22.5 mm.; diameter, 16 mm.

***Nucula panamina* Dall.**

Nucula panamina Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 368, pl. 6, fig. 11. U. S. S. Albatross, station 3360, "Gulf of Panama, in 1672 fathoms, sand, bottom temperature 42° F."

Type Locality: Gulf of Panama, in 1,672 fathoms, sand. Type No. 122,894 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell large, thick, solid, rather donaciform with dark polished olivaceous periostracum; interior more or less radially striate, but valve margins smooth and entire; hinge with 20 anterior and 10 posterior teeth. Length 22 mm.; height, 16 mm.; diameter, 9 mm.

***Nucula paytensis* A. Adams.**

Nucula paytensis A. Adams, *Proc. Zool. Soc. London*, 1856, p. 51. "Hab. Payta, Peru. Mus. Cuming." —Sowerby, *Conch. Icon.*, Vol. 18, *Nucula*, October, 1870, sp. 23, pl. 3, fig. 23. "Hab. Payti, Peru." —Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 250. Paita, Peru.

[*Nucula crenulata*] var.? *N. paytensis* A. Adams, Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 154, pl. 230 (*Nuculidae*, pl. 5), figs. 160 and 161. [No locality cited].

Type Locality: Paita, Peru.

Range: Known only from the type locality.

A very oblique, ovate, gibbose species, concentrically grooved and decussately striated (A. Adams).

***Nucula pigafettae* Dall.**

Nucula pigafettae Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 369. U. S. S. Albatross, station 2780, "Magellan Straits, in 369 fathoms, mud, bottom temperature 47° F."

Type Locality: Magellan Straits, in 369 fathoms, mud. Type No. 96,243 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell small, inequilateral, with blackish-brown or dark olivaceous periostracum; irregularly concentrically striated and sometimes very minutely radiately striated but not visibly reticulate; hinge with 15-17 anterior and 7 posterior teeth; margins of valves entire. Length, 15 mm.; height, 10.5 mm.; maximum diameter, 7.5 mm.

Nucula pisum Sowerby.

Nucula pisum Sowerby, *Proc. Zool. Soc. London*, 1832 (issued March 13, 1833), p. 198. "Hab. ad Valparaíso." "Dredged in coarse sand and gravel, at various depths from seven to forty fathoms." —Sowerby, *Conch. Illustr., Nuculae*, 1833, p. 6, pl. 16, fig. 23. Valparaíso. —Hanley, *Cat. Rec. Biv. Shells*, p. 172, 1843, p. 376, 1856?, Suppl. 20, fig. 12, 1856. Valparaíso. —Hupé, *Hist. de Chile, Zool.*, Vol. 8, 1854, p. 304. Valparaíso, etc. —Hanley, *Thes. Conch.*, Vol. 3, *Nuculidae*, 1860, p. 153, pl. 229 (*Nuculidae*, pl. 4), fig. 133. Valparaíso, Chile. —Philippi, *Los Fos. Terc. i. Cuart. Chile*, 1887, p. 190, pl. 41, fig. 25. Recent on coast of Chile, also "fósil en la hacienda de La Cueva." —Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 250. Valparaíso to San Blas, Chile.

Type Locality: Valparaíso, Chile, in 7 to 40 fathoms, sand and gravel.

Range: Valparaíso to San Blas, Chile.

Reference to the illustration of *Nucula pisum* given in Reeve's³⁹ *Conchologia Iconica* has been omitted by us from the synonymy of this species because von Ihering⁴⁰, stated that the illustration is definitely that of *N. semiornata* d'Orbigny, an Atlantic species.

Nucula savatieri Mabilie & Rochebrune.

Nucula savatieri Mabilie & Rochebrune, *Miss. Sci. Cap Horn*, Vol. 6, *Zool.*, pt. 2, 1889, p. H 112, pl. 8, figs. 2a, 2b, 2c. "Hab. —Canal du Beagle. Baie Orange." —Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 367, pl. 18, fig. 11. Gulf of Panama, in 322 fathoms; 24 miles off Aguja Point, Peru, in 1036 fathoms; on the west coast of Patagonia in 122 fathoms; Straits of Magellan, in 77 fathoms.

Type Locality: Beagle Canal and Orange Bay, Chile.

Range: Straits of Magellan, Patagonia, to the Gulf of Panama.

Shell compressed-ovate, very inequilateral, pale olive periostracum; valves with smooth entire margins; hinge with 24 anterior and 10 posterior teeth. Length, 14-21 mm.; height, 10-15 mm.; diameter, 5-8 mm.

Nucula taeniolata Dall.

Nucula taeniolata Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 368, pl. 7, figs. 3 and 5. U. S. S. *Albatross*, station 3417, "off Acapulco, Mexico, in 493 fathoms, mud, bottom temperature 40.6° F." —Heath, *Mem. Mus. Roy. d'Hist. Nat. Belg.*, Ser. 2, Fasc. 10, 1937, pp. 4, 6, 17, pl. 3, fig. 24 (Anatomy). Acapulco, Mexico, in 493 fathoms.

Type Locality: Off Acapulco, Mexico, in 493 fathoms, mud. Type No. 122,897 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell elongate, almost rostrate, thin, polished, and with dark olive-colored periostracum, more or less minutely irregularly wrinkled with a few very faint almost microscopic irregularly distributed radial striae; margins of valves simple, smooth; hinge with 10 anterior and 6 posterior teeth. Length 17 mm.; height, 11 mm.; diameter, 6.5 mm.

³⁹ *Nucula pisum* Sowerby, Sowerby, *Conch. Icon.*, Vol. 18, *Nucula*, October, 1870, sp. 24. pl. 4, fig. 24.

⁴⁰ von Ihering, H., *An. Mus. Nac. Buenos Aires*, Ser. 3, Vol. 7, 1907, p. 227.

***Nucula tanneri* Dall.**

Nucula tanneri Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 367. "Straits of Magellan at station 2780, in 369 fathoms, mud, bottom temperature 47°F." Also on the west coast of Patagonia, in 61 to 348 fathoms, mud, temperature 48° to 54°.

Type Locality: Straits of Magellan, in 369 fathoms, mud. Type No. 96,243 U. S. Nat. Mus.

Range: Straits of Magellan and west coast of Patagonia.

Shell oval, inequilateral, brownish periostracum with concentric zones of darker and lighter shade; sculpture of faint concentric ripples; margins smooth; hinge with 14-17 anterior and 7-9 posterior teeth. Length, 22.5 mm.; height, 16.5 mm.; diameter, 10.0 mm.

Genus *Acila* H. & A. Adams.

Acila H. & A. Adams, *Gen. Rec. Moll.*, Vol. 2, January, 1858, p. 545. ——— Stoliczka, *Mem. Geol. Surv. India, Palaeont. Indica*, Cret. Fauna South India. Vol. 3, 1871, p. 325. "*N. divaricata*, Hinds, is the type." ——— Schenck, *Geol. Soc. America, Spec. Publ.* No. 4, 1936. See especially pp. 7-44.

Type (designated by Stoliczka): *Nucula divaricata* Hinds. [*Proc. Zool. Soc. London*, 1843, p. 97. China Sea; from eighty-four fathoms. ——— Hinds, *Zool. Voy. Sulphur*, Moll. pt. 3, 1844 [January, 1845 on cover of pt. 3], p. 62, pl. 18, fig. 4. "Inhab. China Sea. From eighty-four fathoms." ——— Sowerby, *Conch. Icon.*, Vol. 18, *Nucula*, October, 1870, sp. 29, pl. 4, fig. 29. "*Hab. Chinese Seas*." ——— Schenck, *Geol. Soc. America, Spec. Publ.* No. 4, 1936, p. 90, pl. 15, figs. 1-10; text fig. 8 (1, 2). Earlier records cited].

The species of the genus *Acila* are characterized by the presence of divaricate sculpture on the shell.

A recent monograph by Schenck⁴¹ of the members of this group should be consulted for information regarding the species of *Acila*. The genus is known from Cretaceous to Recent.

Subgenus *Truncacila* Schenck in Grant & Gale.

Truncacila Schenck in Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, November 3, 1931, p. 115. Type: *Nucula castrensis* Hinds. ——— Schenck, *Geol. Soc. Amer., Special Publ.* No. 4, July 18, 1936, p. 23. Type: *Nucula castrensis* Hinds.

Type (by original designation): *Nucula castrensis* Hinds.

Shell without the shallow sinus characteristic of the typical section of *Acila*, the posterior end being truncated, as a rule, nearly at right angles (Grant & Gale).

***Acila (Truncacila) castrensis* Hinds.**

Nucula castrensis Hinds, *Proc. Zool. Soc. London*, 1843, p. 98. "*Hab. Sitka, Northwest America. A single specimen was dredged in the harbour, from seven fathoms, sand.*" ——— Hinds, *Zool. Voy. Sulphur*, Moll., Pt. 3, 1844 [Jan. 1845 on cover of Pt. 3], p. 63, pl. 18, fig. 5. "Inhab. Sitka, North-west America. A single specimen was dredged in the harbour, from seven fathoms, sand." ——— Sowerby, *Conch. Icon.*, Vol. 18, *Nucula*, October, 1870, sp. 32, pl. 4, fig. 32. "*Hab. North-West America.*"

Nucula lyalli Baird, *Proc. Zool. Soc. London*, 1863, p. 71. "*Hab. Esquimalt Harbour, Vancouver Island; dredged by Dr. Lyall in 8 to 10 fathoms.*"

Acila castrensis Hinds, Ashley, *Proc. Calif. Acad. Sci.*, Ser. 2, Vol. 5, 1895, pp. 327, 344. Purisima and Tunitas Creek, San Mateo County, California, Pliocene.

⁴¹ Schenck, H. G. *Nuculid Bivalves of the genus Acila. Geol. Soc. America, Special Publ.* No. 4, July, 1936, 149 pp., 18 pls.

Also Miocene to Recent. —Frizzell, *Nautilus*, Vol. 44, no. 2, 1930, pp. 50-53. Friday Harbor, Puget Sound, Washington, Recent. —Haas, Dr. H. G. Bronns Klassen u. Ordnung des Tierreichs, Moll., Bivalvia, Bd. 3, Lief. 4, 1933, pp. 529-531, fig. 258.

Nucula (Acila) castrensis Hinds, I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, no. 1, 1924, p. 14, pl. 5, fig. 11; pl. 37, figs. 1, 2. Bering Sea to San Diego, California, also Miocene, Pliocene and Pleistocene. —Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 116, pl. 1, figs. 6a, 6b. Earlier records cited, Miocene to Recent.

Acila (Truncacila) castrensis Hinds, Schenck, *Geol. Soc. America, Special Publ.* No. 4, 1936, p. 96, pl. 10, figs. 1-15; pl. 14, figs. 2, 3; text figure 7 (2-5). Pliocene to Recent. Earlier records cited with discussion of the species.

Type Locality: Sitka, Alaska, dredged in harbor in 7 fathoms.

Range: Sitka, Alaska, to Cedros Island, Lower California, 40 to 262 fathoms.

Collecting Station: Mexico: East of Cedros Island (126-D-10). 60 fathoms, crushed shell and eel grass bottom.

A single valve of *Acila castrensis* was dredged about 1¼ miles east of Cedros Island. This is a southern extension in the range of the species. Heath⁴² has recently discussed the soft parts of *A. castrensis* and Schenck has discussed the species in detail in his work on *Acila*.

Family Nuculanidae.

The shells of the Nuculanidae are somewhat similar to those of the Nuculidae but the posterior end is elongate and rostrate; the ends of the shell are sometimes partly gaping; a ligament is present, often behind the beaks; the interior of the shell is porcellaneous or sub-nacreous; the pallial line is sinuate due to the presence of siphons.

Most of the species of the Nuculanidae dwell in muddy portions of the bottom of the sea.

No representatives of *Yoldia*, *Cyrella*, *Malletia* or of *Tindaria* are present in the collections made by Crocker and Beebe from west American waters. This may be explained in part by the fact that most of the species of such genera as *Yoldia* and *Tindaria* in the region covered by these expeditions occur at depths considerably greater than those from which most of the collections were secured.

KEY TO THE GENERA OF NUCULANIDAE.

- A. No lateral teeth on hinge line
 - a. Ligament internal *Nuculana*
 - aa. Ligament external
 - b. Shell pointed posteriorly
 - c. Shell veneriform, thickened *Tindaria*
 - cc. Shell elongate
 - d. Shell lanceolate, length more than double width *Adrana*
 - dd. Shell broader, length about one third greater than width *Yoldia*
 - bb. Shell rounded posteriorly *Malletia*
- B. A well developed lateral tooth in right valve with corresponding depression in left; shell very small *Cyrella*

⁴² Heath, H. *Mem. Mus. Roy. d'Hist. Nat. Belg.*, Ser. 2, Fasc. 10, 1937, pp. 4, 9, etc. pl. 4, figs. 30, 36; pl. 6, fig. 50; pl. 9, figs. 76, 77. See also Hilton, W. A., *Jour. Entomol. & Zool.*, Vol. 11, no. 4, 1919, p. 77, figs. 1-7. Monterey Bay, California, in 60-80 fathoms, and south of Alaskan Peninsula, in 483 fathoms.

Genus *Nuculana* Link.

Nuculana Link, Beschreib. Nat.-Samml. Univ. Rostock, Abt. 3, May 17, 1807, p. 155. Sole species: "*N. rostrata*" [Chemnitz]. — Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 118. Type: *Arca rostrata* Chemnitz.

Leda Schumacher, *Essai Nouv. Syst. Test.*, 1817, pp. 55, 172, 173. Type: *Arca rostrata* Chemnitz. Illustrated by Schumacher on pl. 19, fig. 4.

Type (by monotypy): *Arca rostrata* Chemnitz. [Neues Syst. Conchyl.-Cab., Bd. 7, 1784, p. 206, pl. 55, figs. 550, 551. Recent, northern coasts of Europe. — Montagu, *Suppl. Test. Brit.*, 1808, p. 55, pl. 27, fig. 7. Norwegian and Baltic Seas, also Scotland].

The genus *Nuculana* and closely related forms originated in the Paleozoic. *Praeleda* Pfab⁴³ has been described from the Silurian of Bohemia and has been recorded from the Ordovician of Belgium. The genus *Nuculana* is widely distributed but the majority of the species occur on muddy bottoms in cold water. Verrill & Bush⁴⁴ published a revision of the genera of the Nuculanidae of the Atlantic coast of the United States. Stewart⁴⁵ has discussed some of the superspecific groups in the Nuculanidae as has Iredale⁴⁶ and Prashad⁴⁷.

KEY TO THE SPECIES OF *Nuculana*.

A. Umbos distinctly anterior

- a. Surface smooth or with very feeble sculpture
 - b. Hinge with 15 anterior and 22 posterior teeth *loshka*
 - bb. Hinge with 15 anterior and 38 posterior teeth *peruviana*
- aa. Surface with distinct concentric sculpture
 - c. Umbos at about the anterior fourth
 - d. Posterior dorsal margin nearly straight *hamata*
 - dd. Posterior dorsal margin strongly concave *cordyla*
 - cc. Umbos at about the anterior third
 - e. Anterior end with a distinct radiating ray or shallow groove
 - f. Size small, length about 6 mm. *acuta*
 - ff. Size large, length about 20 mm. or more
 - g. Concentric sculpture fine, weak *marella*
 - gg. Concentric sculpture strong, distant riblets *costellata*
 - ee. Anterior end without a radiating ray or groove or if present, very weak

⁴³ *Praeleda* Pfab, *Palaeontogr.*, Bd. 80, Abt. A, Lief. 4-6, April, 1934, p. 231. "Typus des genus: *P. compar* (Barr.)."

⁴⁴ Verrill, A. E., & Bush, H. J. Revision of the genera of *Ledidae* and *Nuculidae* of the Atlantic Coast of the United States. *Amer. Jour. Sci.*, Ser. 4, Vol. 3, 1897, pp. 51-63, 22 figs. in text. — *Proc. U. S. Nat. Mus.*, Vol. 20, 1898, pp. 775-901.

Yonge (Phil. Trans. Roy. Soc. London, Ser. B, Biol. Sci., No. 566, Vol. 230, August 9, 1939, pp. 79-147, 1 pl., 39 figs. in text) has discussed the anatomy of the protobranchiate mollusks.

⁴⁵ Stewart, R. B., *Acad. Nat. Sci. Philadelphia, Spec. Publ. No. 3*, 1930, pp. 48-64.

⁴⁶ Iredale, T., *Rec. Austral. Mus.*, Vol. 17, no. 4, 1929, pp. 153-159. — *Brit. Mus. (Nat. Hist.) Great Barrier Reef Exped. 1928-29. Sci. Repts. Vol. 5, no. 6, Moll. Pt. 1*, 1939, pp. 238-241. In this paper three new genera of Nuculanidae are proposed. *Eptoleda*, "Type: *Leda darwini* Smith"; *Zygonoleda*, "Type: *Z. corbuloides minutalis* subsp. nov."; *Tepidoleda*, "Type: *T. lata* orion subsp. nov."

Powell (*Proc. Malacol. Soc. London*, Vol. 21, pt. 4, March, 1935, pp. 252-255, pl. 27), has described some Recent and Tertiary Nuculanidae from New Zealand.

⁴⁷ Prashad, B., *Siboga Exped.*, Vol. 53c, Lamell., 1932, pp. 18-19.

- h. Anterior end without radiating ray or groove
 - i. Without deeply impressed lines near base *calcar*
 - ii. With 6 to 8 impressed lines near base, not coincident with lines of growth *calcarella*
- hh. Anterior end with a very weak radiating ray or groove *cuneata*
- B. Umbos central or subcentral
 - a. Sculpture faint or obsolete over most of the shell
 - b. Striae obsolete on central portion of shell; no radials
 - c. Size large, conspicuous oblique striae posteriorly, length about 35 mm. *polita*
 - cc. Size smaller, no oblique posterior striae, length about 15 mm. *pontonia*
 - bb. Striae present on basal margin, radially rippled *acrita*
 - aa. Sculpture strong, continuous, concentric
 - d. Posterior dorsal area defined by two ridges or angles
 - e. Anterior end with a radial ray or groove
 - f. Concentric ridges evenly spaced
 - g. Radiating lyrae well developed
 - h. Radiating lyrae over entire shell *hindsii*
 - hh. Radiating lyrae confined to posterior end *crispa*
 - gg. Radiating lyrae, if present, very fine, confined to the umbonal region
 - i. Anterior groove shallow, barely discernible *eburnea*
 - ii. Anterior groove very conspicuous *ornata*
 - ff. Concentric ridges not evenly spaced
 - j. Ridges widely spaced toward umbos, close toward margin *impar*
 - jj. Ridges irregularly spaced *elenensis*
 - ee. Anterior end without a radial ray or groove
 - k. Posterior end obtuse (60°), shell thin, fragile *agapea*
 - kk. Posterior end acute, shell solid *bicostata*
 - dd. Posterior dorsal area with not more than one ridge or angle
 - l. size small, length less than 25 mm.
 - m. Dorsal area defined by one ridge, posterior end attenuated.
 - n. Concentric sculpture extending at least to posterior dorsal ridge
 - o. Size about 15 to 20 mm.
 - p. Anterior hinge teeth 26, posterior 20 *callimene*
 - pp. Anterior hinge teeth 12, posterior 12 *taphria*
 - oo. Size smaller, length 10 mm. or less
 - q. Length about 10 mm. *excavata*
 - qq. Length about 5 mm. *oxia*
 - nn. Shell smooth, at least in front of posterior dorsal ridge *laeviradius*

KEY TO THE SPECIES OF *Nuculana* (continued):

- mm. Posterior dorsal area without ridge or angle, both ends rounded
 - r. Anterior end without a radiating ray or groove
 - s. Posterior end attenuated but not acute *rhytida*
 - ss. Both ends evenly rounded *lobula*
 - rr. Anterior end with a radiating ray or groove *lucasana*
- ll. Size large, shell heavy, length over 30 mm. *gibbosa*

Subgenus **Saccella** Woodring.

Ledina Sacco, Moll. Terr. Terz. Piemonte e Liguria, Pt. 26, December, 1898, p. 53. "(tipo *L. fragilis* (Chemnitz).)"

Not *Ledina* Dall, *Trans. Wagner Free Inst. Science*, Vol. 3, pt. 4, April, 1898, p. 580. Type: *Leda eborea* Conrad, 1860 (not *L. eborea* Conrad, 1846) = *L. smirna* Dall, Eocene of Gulf States of United States.

Saccella Woodring, *Carnegie Inst. Washington, Publ. No. 366*, May 20, 1925, p. 15. Type: *Arca fragilis* Chemnitz (= *Leda commutata* Philippi). New name for *Ledina* Sacco not *Ledina* Dall.

Type (by original designation): *Arca fragilis* Chemnitz. [Neues Syst. Conchyl.-Cab., Bd. 7, 1784, p. 199, pl. 55, fig. 546. "Mittelländischen Meeres." —Bucquoy, Dautzenberg & Dollfus, Moll. Mar. Roussillon, Vol. 2, Fasc. 5 (Pelecypoda, Fasc. 18), 1891, p. 215, pl. 37, figs. 26, 27, 28, 29, 30, 31. Mediterranean, and Atlantic Ocean. (= *Leda commutata* Philippi). Miocene to Recent in the Mediterranean region.]

Saccella resembles *Lembulus*⁴⁸ but the former has concentric instead of diagonal sculpture and has a narrower and shallower posterior groove. *Saccella* occurs Recent and fossil in Europe, eastern and western North and Central America and elsewhere. It has been recorded fossil in the Eocene of California⁴⁹ and Tertiary of New Zealand⁵⁰.

***Nuculana (Saccella) acuta* Conrad.**

Plate I, Figure 11.

Nucula acuta Conrad, Amer. Mar. Conch., 1832, p. 32, pl. 6, fig. 3. North Carolina; Recent.

Leda acuta Conrad, Verrill, *Trans. Connecticut Acad. Arts and Sci.*, Vol. 6, 1884, p. 259, pl. 30, fig. 15. New England Coast. —Dall, *Bull. Mus. Comp. Zool.*, Vol. 12, no. 5, 1886, p. 251, pl. 7, figs. 3a, 3b, 8 [Not all the synonymy]. New England; Florida; Jamaica. —Dall, *Trans. Wagner Free Inst. Sci.*, Vol. 3, pt. 4, 1898, p. 592. Oligocene to Recent on Atlantic Coast. Also Recent on Pacific Coast of California. —Dall & Simpson, *Bull. U. S. Fish Comm.*, Vol. 20, pt. 1, for 1900 (issued separately November 29, 1901), p. 458. Mayaguez Harbor, Porto Rico. —Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 250. California, the Gulf of Panama, and south to Valparaiso, Chile. Also Atlantic. —Gardner, *U. S. Geol. Surv., Prof. Paper 142-A*, 1926, p. 12, pl. 2, figs. 13-16. Eastern North America; Miocene to Recent.

⁴⁸ *Lembulus* Risso, Hist. Nat. l'Europ. Merid., Vol. 4, 1826, p. 319. Type (designated by Gray, 1847): *Lembulus rossianus* Risso (= *Arca pella* Linnaeus). Recent, Mediterranean Sea. Illustrated by Risso, 1826, pl. 11, fig. 166, and by Bucquoy, Dautzenberg & Dollfus, Moll. Mar. Roussillon, Vol. 2, Fasc. 5 (Pelecypoda, Fasc. 18), 1891, p. 218, pl. 37, figs. 32, 33, 34, 35. Mediterranean; Adriatic; Atlantic Ocean.

⁴⁹ Vokes, H. E., *Ann. New York Acad. Sci.*, Vol. 38, 1939, pp. 41-43.

⁵⁰ See *Nuculana (Saccella) duplicarina* Laws, *Trans. and Proc. Roy. Soc. New Zealand*, Vol. 68, pt. 4, March, 1939, p. 468, pl. 62, fig. 2. Pakaurangi Point, Kaipara Harbor, New Zealand. Tertiary. — See also, Marwick, *Geol. Surv. New Zealand, Palaeo. Bull. No. 13*, 1931, pp. 50, 51.

Nuculana acuta Conrad, M. Smith, East Coast Mar. Shells (Edwards Bros., Ann Arbor, Michigan), 1937, p. 26, pl. 2, fig. 2. Off Martha's Vineyard to the West Indies.

Type Locality: North Carolina.

Range: Off Martha's Vineyard, Massachusetts, to the West Indies.

Nuculana acuta has been recorded from various localities on the west coast ranging from Alaska to Chile. Dall in 1909 cited the range as from California south to Chile. In a later work⁵¹ he cited it as occurring from Nazan Bay, Atka Island, Aleutian Islands, Alaska, to the Gulf of California. The species is well known on the Atlantic coast from Massachusetts to the West Indies, but its occurrence in Western America can be considered very doubtful until definitely proved.

***Nuculana (Saccella) callimene* Dall.**

Plate I, Figure 13.

Leda (Jupiteria) callimene Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 372, pl. 17, figs. 3 and 4. "U. S. S. 'Albatross,' Station 3396, Gulf of Panama, 259 fathoms, mud, bottom temperature 47.4° F." Also at Tomé, Chile, in 14 fathoms.

Leda callimene Dall, Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 250. Gulf of Panama to Tomé, Chile. ———Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama.

Type Locality: Gulf of Panama, in 259 fathoms, mud. The type is No. 122,910 U. S. Nat. Mus.

Range: Gulf of Nicoya to Tomé, Chile.

Collecting Station: Costa Rica: 3 miles south of Blanco Island, Gulf of Nicoya. 100 fathoms.

A single specimen of *Nuculana callimene* was dredged in the Gulf of Nicoya. Compared to *N. taphria* Dall it is more elongate, less inflated, and the exterior surface is less polished.

Specimens somewhat similar to *Nuculana callimene* have been recorded by E. K. Jordan⁵² from the Pleistocene of Magdalena Bay, Lower California.

***Nuculana (Saccella) elenensis* Sowerby.**

Plate I, Figures 12, 14, 15, 16, 17, 18, 19, 22.

Nucula elenensis Sowerby, *Proc. Zool. Soc. London*, 1832 (issued March 13, 1833), p. 198. "*Hab.* ad Sanctam Elenam." "Dredged in sandy mud at a depth of six fathoms." Recent. ———Sowerby, *Conch. Illustr.*, *Nuculae*, 1833, p. 4, pl. 15, fig. 14. "St. Elena, Mr. Cumming." ———Müller, *Synop. Test. Viv.*, 1836, p. 191. Type locality cited. ———Reeve, *Conch. Syst.*, Vol. 1, 1841, p. 111, pl. 85, fig. 14. ———Hanley, *Cat. Rec. Bivalve Shells*, 1843, p. 169, Suppl. pl. 19, fig. 56, 1846. "W. Colombia." ———C. B. Adams, *Ann. Lyceum Nat. Hist. New York*, Vol. 5, 1852, p. 478. Panama. Also earlier records cited.

Leda ?elenensis Sowerby, Carpenter, *Cat. Mazatlan Shells*, February, 1856, p. 145. Mazatlan, Mexico. Also earlier records cited.

Leda elenensis Sowerby, d'Orbigny, *Voy. Amér. Mérid.*, Vol. 5, 1846, p. 545. Santa Elena, Ecuador. ———Hanley, *Thes. Conch.*, Vol. 3, 1860, *Leda*, p. 121, pl. 228, [*Nuculidae*, pl. 3], figs. 70, 71, 72. Panama. ———Sowerby, *Conch. Icon.*, Vol. 18, *Laeda*, September, 1871, sp. 32, pl. 6, figs. 32a, 32b. "*Hab.* St. Elena.

⁵¹ Dall, W. H., *U. S. Nat. Mus., Bull.* 112, 1921, p. 10.

⁵² *Leda* sp. aff. *callimene* Dall (young), E. K. Jordan, *Bull. South. Calif. Acad. Sci.*, Vol. 23, pt. 5, September-October (issued October 25), 1924, p. 148. Quaternary at Magdalena Bay, Lower California. ———E. K. Jordan, *Contrib. Dept. Geol. Stanford Univ.*, Vol. 1, no. 4, 1936, p. 112. Previous record cited.

Panama." —Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 251. Santa Elena, Ecuador. —Olsson, *Nautilus*, Vol. 37, no. 4, 1924, p. 126. Salinas, Ecuador.

Leda elenensis Sowerby var. *gibbosa* Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 121.

Leda elenensis Sowerby var. *media* Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 121.

Leda elenensis Sowerby var.? *pyriformis* Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 121.

Leda (Jupiteria) elenensis Sowerby, Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, p. 374, October, 1908. In 52 fathoms in Panama Bay.

Leda (Saccella) acapulcensis Pilsbry & Lowe, *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 84, May 21, 1932, p. 107, pl. 17, figs. 1 and 2. "Mexico: Acapulco, 20 fathoms."

Nuculana acapulcensis Pilsbry & Lowe, Strong, Hanna & Hertlein, *Proc. Calif. Acad. Sci.*, Ser. 4, Vol. 21, no. 10, December 21, 1933, p. 118. Acapulco, Mexico.

Nuculana elenensis Sowerby, Hertlein, *Bull. South. Calif. Acad. Sci.*, Vol. 33, pt. 2, May-August (issued August 31), 1934, p. 65. San Ignacio Lagoon, Lower California; Pleistocene. —E. K. Jordan, *Contrib. Dept. Geol. Stanford Univ.*, Vol. 1, no. 4, 1936, pp. 112, 118. Magdalena Bay, Lower California; Pleistocene. Recent, Panama and Santa Elena, Ecuador.

Nuculana elenense Sowerby, Strong & Hertlein, *Allan Hancock Pacific Exped. (Univ. South. Calif.)*, Vol. 2, no. 12, 1939, p. 183. Bahia Honda, Veragua, Panama; off Taboga Island, Panama.

Type Locality: Santa Elena, Ecuador, in 6 fathoms, sandy mud.

Range: Santa Inez Bay, Lower California, to Salinas, Ecuador.

Collecting Stations: Mexico: Arena Bank, Gulf of California (136-D-13,-18). 40-45 fathoms, mud and Arca conglomerate bottom; Santa Inez Bay, Gulf of California (144-D-2). 2½ fathoms, sand, weed and rock bottom; also (145-D-1,-3, and shore). 4-13 fathoms, sand bottom; Tenacatita Bay (183-D-3). 40 fathoms, sandy mud bottom; Manzanillo (184-D-2). 30 fathoms, gravelly sand bottom; Acapulco (189-D-3). 13 fathoms, mud bottom; 4 miles south-southwest of Maldonado Point (192-D-3). 38 fathoms, mud bottom; Port Guatulco (195-D-19). 17 fathoms, gray mud and crushed shell bottom; Tangola-Tangola Bay (196-D-17). 23 fathoms, mud bottom; Costa Rica: Port Parker (203-D-1,-3). 12-15 fathoms, shelly mud bottom.

Nuculana elenensis Sowerby is a very variable species and as pointed out by Jordan neither the form nor sculpture is constant in a series. Sowerby gave the varietal names, *gibbosa*, *media* and *pyriformis*, to forms of this species. With a very large series of shells from many localities we can find no constant distinguishing feature for separation of Pilsbry & Lowe's species *acapulcensis*. They compared it with *Leda agapea* Dall which we have not seen. The specimens here referred to *elenensis* have a strong groove on the anterior end. This is not shown on the figures of *acapulcensis* Pilsbry & Lowe. We have studied a series of several hundred specimens from Sta. 203-D-3. These agree well with Hanley's figure 71 (*Thes. Conch.*, Vol. 3, pl. 228, *Nuculidae*, pl. 3). Almost none of our specimens show the nearly smooth area near the ventral margin as shown by Pilsbry & Lowe on their pl. 17, fig. 1. One specimen in the collection shows a tendency toward this type of sculpture and in many of the larger specimens there is a definite line beyond which the sculpture is somewhat finer.

Nuculana bicostata Sowerby appears to be distinguished by the presence of two pronounced rostral ribs while there is but one rib on the posterior part of *N. elenensis*. *Nuculana acuta* Conrad is more truncate posteriorly and is more compressed than *N. elenensis*. The shorter and more contracted posterior portion of the shell serves to separate *N. elenensis* from young specimens of *N. peruviana* Dall from Peru.

***Nuculana (Saccella) eburnea* Sowerby.**

Plate II, Figures 1, 2, 3.

Nucula eburnea Sowerby, *Proc. Zool. Soc. London*, 1832 (issued March 13, 1833), p. 198. "Hab. ad oras Columbiae Occidentalis." "Found in sandy mud, at a depth of from seven to nine fathoms, in the Bay of Caraccas." —Sowerby, *Conch. Illustr.*, *Nuculae*, 1833, pp. 4, 6, pl. 15, fig. 10. Bay of Caraccas. —Müller, *Synop. Test. Viv.*, 1836, p. 191. Type locality cited. —Reeve, *Conch. Syst.*, Vol. 1, 1841, p. 111, pl. 85, fig. 10. —Catlow, *Conch. Nomencl.*, 1845, p. 53. —Hanley, *Cat. Rec. Bivalve Shells*, p. 169, 1843, 376, ?1856, Suppl. pl. 19, fig. 57, 1846. W. Colombia.

Leda eburnea Sowerby, d'Orbigny, *Voy. Amér. Mérid.*, Vol. 5, 1846, p. 546. "M. Cuming l'a découverte dans la baie de Caracas, sur la côte occidentale de la république de l'Equateur." —Carpenter, *Rept. Brit. Assoc. Adv. Sci.* for 1863 (issued 1864), p. 560. Reprint in *Smithson. Misc. Coll.*, No. 252, 1872, p. 46. Panama; Bay of Caraccas. —Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 124, pl. 228 (*Nuculidae*, pl. 3), fig. 90. Panama; Bay of Caraccas. —Sowerby, *Conch. Icon.*, Vol. 18, *Laeda*, September, 1871, pl. 5, fig. 29. "*Hab. Bay of Panama.*" —Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 250. "Gulf of Panama to the Bay of Caragues, Ecuador." —Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama.

Nucula lyrata Hinds, *Proc. Zool. Soc. London*, 1843, p. 100. "Hab. Panama; from thirty fathoms." —Hinds, *Zool. Voy. Sulphur*, 1844 (January, 1845 on the cover of *Moll.*, Pt. 3), p. 64, pl. 18, fig. 12. Original locality cited.

Type Locality: Bay of Caraccas, Ecuador, in 7 to 9 fathoms, sandy mud.

Range: Meanguera Island, Gulf of Fonseca, El Salvador, to Bay of Caraccas, Ecuador.

Collecting Stations: El Salvador: Meanguera Island, Gulf of Fonseca (199-D-1). 16 fathoms, sandy mud and crushed shell bottom; Nicaragua: Corinto (200-D-19). 12-13 fathoms, mangrove leaves on bottom; Costa Rica: 14 miles southeast of Judas Point (214-D-1 to 4). 42-61 fathoms, mud, shell and rocky bottom.

The shell of *Nuculana eburnea* Sowerby has a smooth or appressed area anterior to the posterior keel somewhat resembling *N. laeviradius* Pilsbry & Lowe. It differs from that species in the great size, more acuminate posterior end and in lacking the elevated ridge on the anterior end which runs from the beaks to the anterior ventral margin on *N. laeviradius*. Specimens of *N. eburnea* in the present collection average about 12.6 mm. in length. *Nuculana lyrata* Hinds, originally described from Panama, was considered to be a synonym of *N. eburnea* by Hanley and Carpenter. From an inspection of the figure given by Hinds it appears likely that *N. lyrata* can be considered synonymous with *N. eburnea*.

***Nuculana (Saccella) gibbosa* Sowerby.**

Plate II, Figures 5, 8.

Nucula gibbosa Sowerby, *Proc. Zool. Soc. London*, 1832 (issued March 13, 1833), p. 198. "Hab. ad littora Peruviae." "Found in soft mud, at a depth of five fathoms, at Tumbes in Peru." "A variety, with a less elevated ridge in the centre of the anterior dorsal margin, and of much smaller size, was found in mud, at twelve fathoms, in the Gulf of Nocoioyo." —Sowerby, *Conch. Illustr.*, *Nuculae*, 1833, p. 4, pl. 15, fig. 9. "Gulf of Nocoioyo. Mr. Cuming." —Deshayes, ed. of Lamarck's *Anim. s. Vert.*, Vol. 6, 1835, p. 508. (as *Nucula gibbosa*. Cuming, but in index it is cited as *Nucula gibbosa*). "Habite les mers du Pérou, près des rivages." —Müller, *Syn. Test. Viv.*, 1836, p. 191. Original locality cited. —Reeve, *Conch. Syst.*, Vol. 1, 1841, p. 111, pl. 85, fig. 9. —Hanley, *Cat. Rec. Bivalve Shells*, p. 169, 1843, p. 376, ?1856, Suppl. pl. 19, fig. 55, 1846. Peru.

Leda gibbosa Sowerby, d'Orbigny, Voy. Amér. Mérid., Vol. 5, 1846, p. 545. "Côte de Payta (Pérou)." —Hanley, Thes. Conch., Vol. 3, *Nuculidae*, 1860, p. 120, pl. 228 (*Nuculidae*, pl. 3), fig. 79. Peru. —Sowerby, Conch. Icon., Vol. 18, *Laeda*, November, 1871, sp. 51, pl. 8, fig. 51. "Hab. Peru." —Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 251. Gulf of Panama to Paita, Peru. —Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama. —Strong, Hanna & Hertlein, *Proc. Calif. Acad. Sci.*, Ser. 4, Vol. 21, no. 10, 1933, p. 118. Acapulco, Mexico.

Leda (Jupiteria) gibbosa Sowerby, Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, 1908, p. 372. Panama Bay in 26 to 47 fathoms, mud.

Nuculana gibbosa Tomlin, *Jour. Conch.*, Vol. 18, no. 7, 1928, p. 189. Coiba Island, Panama, in 10 fathoms. Gorgona Island, Colombia, in 20 fathoms.

Type Locality: Tumbez, Peru, in 5 fathoms, soft mud.

Range: Acapulco, Mexico, to Tumbez, Peru.

Collecting Stations: Mexico: Tangola-Tangola Bay (196-D-19). 30 fathoms, mud bottom; Costa Rica: off Ballena Bay, Gulf of Nicoya (213-D-11-17). 35-45 fathoms, mud bottom.

This is a thick, elongate, posteriorly pointed shell with fairly gibbous beaks. It is ornamented by strong concentric somewhat upturned ribs which are separated by smooth bottomed grooves.

***Nuculana (Saccella) impar* Pilsbry & Lowe.**

Plate II, Figure 6.

Leda impar Pilsbry & Lowe, *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 84, May 21, 1932, p. 106, pl. 17, figs. 3, 4, 5, 6. "Mexico: Guaymas, 20 fathoms." —Hertlein, *Bull. South. Calif. Acad. Sci.*, Vol. 33 pt. 2, May-August (issued August 31), 1934, p. 62. Maria Magdalena Island, Tres Marias Islands; Pleistocene. —Lowe, *Trans. San Diego Soc. Nat. Hist.*, Vol. 8, no. 6, 1935, p. 27. Punta Penasco, Sonora, Mexico.

Type Locality: Guaymas, Mexico, in 20 fathoms. Type No. 155636 Acad. Nat. Sci. Philadelphia.

Range: Punta Penasco, Sonora, Mexico, to Port Parker, Costa Rica.

Collecting Stations: Mexico: Santa Inez Bay, Gulf of California (145-D-1,-3). 4-13 fathoms, sand bottom; Costa Rica: Port Parker (203-D-3). 12 fathoms, shelly mud bottom.

The sculpture of this species is characteristic. This consists of concentric ridges, which are fine and close on the beaks, then widely spaced, then again becoming closer and about equal to their intervals from about the middle of the valves to the ventral margin.

***Nuculana (Saccella) laeviradius* Pilsbry & Lowe.**

Plate II, Figures 4, 7.

Leda laeviradius Pilsbry & Lowe, *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 84, May 21, 1932, p. 106, pl. 17, fig. 7. "Mexico: Guaymas, 20 fathoms."

Leda leviradius Pilsbry & Lowe, Lowe, *Trans. San Diego Soc. Nat. Hist.*, Vol. 8, no. 6, 1935, p. 27. Punta Penasco, Sonora, Mexico.

Type Locality: Guaymas, Mexico, in 20 fathoms. Type No. 155635 Acad. Nat. Sci. Philadelphia.

Range: Punta Penasco, Sonora, Mexico, to Port Parker, Costa Rica.

Collecting Stations: Mexico: Santa Inez Bay, Gulf of California (145-D-1,-3). 4-13 fathoms, sand bottom; Costa Rica: Port Parker (203-D-1,-3). 12-15 fathoms, sandy mud, crushed shell and shelly mud bottom.

The presence of a smooth band preceding the posterior ridge and the strong hinge in proportion to the size of the shell are characteristic features of this species. In some specimens a considerable portion of the exterior of the shell is smooth.

***Nuculana (Saccella) taphria* Dall.**

Nucula caelata Hinds, *Proc. Zool. Soc. London*, December, 1843, p. 99. "Hab. California, between 38° 18' and 34° 24' north latitude; namely, at Russian Bodegas, San Francisco, and Santa Barbara, in from six to ten fathoms." "Cab. Belcher." —Hinds, *Zool. Voy. Sulphur, Moll.*, pt. 3, 1844 [January, 1845 on cover of pt. 3], p. 64, pl. 18, fig. 13. Original locality cited.

Not *Nucula coelata* Conrad, *Amer. Jour. Sci.*, Vol. 23, no. 2, January, 1833, p. 343. Claiborne, Alabama. London Clay. [Eocene].

Leda caelata Hinds, Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 129, pl. 228 (*Nuculidae*, pl. 3), figs. 95, 96. California. — Sowerby, *Conch. Icon.*, Vol. 18, *Laeda*, February, 1871, sp. 6, pl. 2, figs. 6a, 6b. "Hab. California."

Leda taphria Dall, *Nautilus*, Vol. 10, no. 6, Oct., 1896, p. 70. New name for *Nucula caelata* Hinds, not *Nucula caelata* Conrad, 1833. Claiborne, Eocene. — Dall, *Nat. Hist. Soc. Brit. Columbia, Bull.* No. 2, January, 1897, p. 7 (in text), pl. 2, figs. 6 and 8. Bodega Bay, California to San Diego. — Arnold, *Proc. U. S. Nat. Mus.*, Vol. 32, 1907, p. 544, pl. 48, figs. 5, 5a. Pliocene to Recent in the California Province. — I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, no. 1, 1924, p. 16, pl. 37, figs. 7, 7a, 8. Bodega Bay, California to Lower California. Also Miocene to Recent in California.

Nuculana taphria Dall, Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 121, pl. 1, figs. 8 and 9. Earlier records cited. Miocene to Recent. — Hertlein, *Bull. South. Calif. Acad. Sci.*, Vol. 33, pt. 2, May-August (issued August 31), 1934, p. 62. Maria Magdalena Island, Tres Marias Islands; Pleistocene. — E. K. Jordan, *Contrib. Dept. Geol. Stanford Univ.*, Vol. 1, no. 4, 1936, p. 112. Magdalena Bay, Lower California (Dall); Pleistocene. — Willett, *Trans. San Diego Soc. Nat. Hist.*, Vol. 8, no. 30, 1937, p. 386. About 2 miles NE. of Playa del Rey, Baldwin Hills, Los Angeles County, California; Upper Pleistocene.

Type Locality: Bodega Bay, California, in 6 to 10 fathoms.

Range: Bodega Bay, California, to Punta Arena, Lower California.

Collecting Stations: Mexico: East of Cedros Island (126-D-12). 45 fathoms, crushed shell and mud bottom; Arena Bank, Gulf of California (136-D-22). 45 fathoms, mud bottom.

The concentric sculpture on this species is uniform and prominent. The beaks are nearly central and the rostrum is rather bluntly pointed.

Heath⁵³ has studied the soft parts of this species.

Subgenus ***Politoleda*** Hertlein & Strong, nov.

Type: *Nucula polita* Sowerby.

Shell elongate, posteriorly pointed. Sculpture consists of very fine concentric lines of growth, and on the lower half of the shell fine wavy incised lines which on the whole posterior dorsal part of the shell are nearly parallel to the posterior dorsal margin.

***Nuculana (Politoleda) polita* Sowerby.**

Plate II, Figure 9.

Nucula polita Sowerby, *Proc. Zool. Soc. London*, 1832 (issued March 13, 1833), p. 198. "Hab. ad Panamam." "A single specimen of this very beautiful species was dredged up in sand from a depth of seven fathoms." — Sowerby,

⁵³ Heath, H., *Mem. Mus. Roy. d'Hist. Nat. Belgique*, Ser. 2, Fasc. 10, 1937, pp. 5, 6, etc., pl. 7, figs. 59, 60.

Conch. Illustr., *Nuculae*, March 8, 1833, p. 4, pl. 15, fig. 11. "Panama. Mr. Cuming."
 —Deshayes, ed. of Lamarck's Anim. s. Vert., Vol. 6, 1835, p. 507. Panama.
 —Hanley, Cat. Bivalve Shells, p. 169, 1843, Suppl. pl. 19, fig. 53, 1846.
 Panama. —Müller, Syn. Test. Viv., 1836, p. 190. "Legit H. Cuming ad Panamam."
 —Reeve, Conch. Syst., Vol. 1, 1841, p. 111, pl. 85, fig. 11.

Leda polita Sowerby, Hanley, Thes. Conch., Vol. 3, *Leda*, 1860, p. 125, pl. 228 (*Nuculidae*, pl. 3), fig. 68. Panama. —Sowerby, Conch. Icon., Vol. 18, *Laeda*, September, 1871, sp. 16, pl. 3, fig. 16. "*Hab. Panama.*" —Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama. —Pilsbry & Lowe, *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 84, p. 141, 1932. On the beach at Old Panama.

Nuculana polita Sowerby, Strong & Hertlein, *Allan Hancock Pac. Exped. (Univ. South. Calif.)*, Vol. 2, no. 12, 1939, p. 183. Beach near Panama Vieja (Old Panama).

Type Locality: Panama, in 7 fathoms, sand.

Range: Champerico, Guatemala, to Panama.

Collecting Stations: Guatemala: 7 miles west of Champerico (197-D-1-2). 14 fathoms, mud bottom; El Salvador: La Libertad (198-D-2). 14 fathoms, mud bottom; Meanguera Island, Gulf of Fonseca (199-D-1). 16 fathoms, sand, mud, and crushed shell bottom; Panama: Gulf of Chiriqui (221-D-1-5). 35-40 fathoms, sandy mud bottom.

The shell of *Nuculana polita* is oblong, anteriorly beaked, ornamented by subdued concentric striae and by oblique striae on the lower part and over the whole posterior portion of the shell. Young specimens 15 mm. in length lack the oblique striae. Specimens reach a length of 45 mm. *Nuculana guppyi* Dall⁵⁴ from the Miocene of Trinidad bears some similarity to *N. polita* but has a more attenuated shell and the beaks are more anterior.

Subgenus **Costelloleda** Hertlein & Strong, nov.

Type: *Nucula costellata* Sowerby.

Shell elongate and with strong concentric sculpture. *Costelloleda* is somewhat similar in general appearance to *Poroleda* Iredale⁵⁵ and *Thestyloda* Iredale.

***Nuculana (Costelloleda) costellata* Sowerby.**

Plate II, Figure 10.

Nucula costellata Sowerby, *Proc. Zool. Soc. London*, 1832 (issued March 13, 1833), p. 198. "*Hab. ad Panamam.*" "Two specimens were taken in sandy mud at a depth of ten fathoms." —Sowerby, Conch. Illustr., *Nuculae*, 1833, p. 4, pl. 15, fig. 8. "Panama." —Müller, Syn. Test. Viv., 1836, p. 191. "Legit H. Cuming ad Panamam." —Reeve, Conch. Syst., Vol. 1, 1841, p. 110, pl. 85, fig. 8. —Hanley, Cat. Rec. Bivalve Shells, p. 169, 1843, p. 376, ?1856, Suppl. pl. 19, fig. 54, 1846. "Panama."

Leda costellata Sowerby, Hanley, Thes. Conch., Vol. 3, 1860, p. 111, pl. 228 D-1,-4). 25-29 fathoms, mud, crushed shell and sand bottom; Cape San Lucas, September, 1871, sp. 24, pl. 4, fig. 24. "*Hab. Panama.*" —Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 37. Panama. —Strong, Hanna & Hertlein, *Proc. Calif. Acad. Sci.*, Ser. 4, Vol. 21, no. 10, 1933, p. 118. Acapulco, Mexico.

Leda (Leda) costellata Sowerby, Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, p. 375, 1908. Gulf of California to Panama. Sta. 2823, in 26 fathoms.

⁵⁴ See *Leda guppyi* Dall, Maury, *Bull. Amer. Paleo.*, Vol. 10, Bull. No. 42, p. 174 (22), pl. 28 (12), fig. 3, 1925. Manzanilla, Trinidad; Miocene.

⁵⁵ *Poroleda* Tate, *Jour. Roy. Soc. New South Wales*, Vol. 27, 1893, p. 186. "Examples: —*Scaphula* (?) *elongata*, Hutton, *Trans. N. Z. Inst.*, XVII, p. 332, 1885. *Poroleda lanceolata*, Tate." —Cotton & Godfrey, *Moll. South Australia*, Pt. 1. Handbook of Flora and Fauna of South Australia, issued by South Australian Branch Brit. Sci. Guild, Adelaide, 1938, p. 45. *Type: Poroleda lanceolata* Hutton [Tate, 1893, p. 186, pl. 12, fig. 6. Gellibrand River, Australia; Eocene].

Leda rostellata Sowerby, Pilsbry & Lowe, *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 84, 1932, p. 141. Acapulco, Mexico, dredged in 20 fathoms.

Type Locality: Panama, in 10 fathoms, sandy mud.

Range: Santa Inez Bay, Lower California, to Panama.

Collecting Stations: Mexico: Santa Inez Bay, Gulf of California (143-D-1,-4). 25-29 fathoms, mud, crushed shell and sand bottom; Cape San Lucas, Lower California; El Salvador: Meanguera Island, Gulf of Fonseca (199-D-1). 16 fathoms, sand, mud and crushed shell bottom; Costa Rica: 14 miles southeast of Judas Point (214-D-1-4). 42-61 fathoms, mud, shell and rocks on bottom.

Oblong, thin, covered with small concentric acute riblets; anteriorly beaked and acuminate, with two dorsal approximated and crenulated ribs (Hanley).

Several specimens of *Nuculana costellata* were collected, usually only one or two at a locality. Most of these specimens are very large compared to those which have appeared previously in the literature, but they do not differ otherwise.

*Nuculana flexuosa*⁶⁶, described from the lower Miocene of Florida, was compared to *N. costellata* by Heilprin but judging from the figures it does not appear to be very closely related to the west coast species.

***Nuculana (Costelloleda) marella* Hertlein, Hanna & Strong, sp. nov.**

Plate II, Figures 12, 13.

[?] *Leda cestrota* Dall, Pilsbry & Lowe, *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 84, 1932, p. 141. "Dredged at 20 fathoms. Acapulco."

Not *Leda cestrota* Dall, *Proc. U. S. Nat. Mus.*, Vol. 12, 1889, p. 255, pl. 13, fig. 7. "Hab. Station 2145, near Colon (Aspinwall), in 25 fathoms, mud."

Shell elongate, slender, compressed, thin, narrowly rostrate, white under a thin light brown epidermis; beaks low, at about the anterior third, posterior dorsal margin only moderately concave and the anterior slightly convex; sculptured with numerous, fine, close spaced concentric laminae; lunular depression very narrow, smooth; escutcheon long, narrow, microscopically striated, the valve margins distinctly elevated, bounded on each valve with two rays separated by a shallow depression running from the beaks to the end of the rostrum, on which the concentric laminae are stronger but flattened; anterior end with a broad, shallow depression running from the beaks to the basal margin; interior polished, hinge with 32 small teeth on the anterior side and about 50 on the posterior side of the central pit. The type measures: longitudinal diameter, 32 mm.; vertical diameter, 11.3 mm.; thickness of the two valves, 5.0 mm.

Holotype, a single specimen, is without definite locality although it probably came from the Gulf of California because it was collected during the expedition to the Gulf of California in 1936. About a dozen single valves and one specimen with both valves were collected at Sta. 221-D-1-5. Lat 7° 54' 15" to 7° 52' 30" N., Long. 82° 02' 45" to 82° 01' 00" W., Gulf of Chiriqui, Panama, 35-40 fathoms, sandy mud bottom.

This species bears a slight resemblance to *Nuculana costellata* Sowerby, but is larger, more rostrate and possesses finer concentric sculpture. The new species bears some resemblance to *Nuculana cestrota* Dall, a species described from the Caribbean and reported by Pilsbry & Lowe from Acapulco, Mexico. The shell of *N. marella* has a greater altitude in proportion to the

⁶⁶ *Leda flexuosa* Heilprin, *Trans. Wagner Free Inst. Sci.*, Vol. 1, 1887, p. 119, pl. 16, fig. 66. From the "Siliceous-bearing marl (Miocene) of Ballast Point, Hillsboro Bay," Florida. - - - Dall, *U. S. Nat. Mus., Bull.* 90, 1915, p. 117, pl. 23, figs. 8 and 10.

length and is therefore not so slender, and the anterior and posterior dorsal slopes are straighter than those of the species described by Dall.

Subgenus *Thestyleda* Iredale.

Thestyleda Iredale, *Rec. Australian Mus.*, Vol. 17, no. 4, September 4, 1929, pp. 158, 187. "Type *Leda ramsayi* E. A. Smith."

Type (by original designation): *Leda ramsayi* E. A. Smith. [Sci. Rept. Voy. Challenger, Zool., Vol. 13, 1885, p. 241, pl. 20, figs. 3, 3a. "off Sydney, New South Wales, in 950 fathoms; green mud."]

Shell of medium size, thin, elongate, umbos slightly tumid, acutely rounded anteriorly, rostrate posteriorly; anterior dorsal slope short, posterior dorsal slope more than twice as long, concave in anterior half then almost straight; ventral margin convexly rounded anteriorly then continuing in an almost straight line to the posterior end which is squarely truncated; ornamented by well marked regular concentric rugae which turn upward at almost a right angle upon crossing the lower keel; two radiating ridges form keels along the rostrum; hinge, consisting of anterior and posterior series of chevron shaped teeth; chondrophore large.

The west American species *Nuculana hamata* and *N. cordyla* appear to be referable to the subgenus *Thestyleda*.

Nuculana (Thestyleda) hamata Carpenter.

Plate II, Figure 14.

Leda hamata Carpenter, *Rept. Brit. Assoc. Adv. Sci.* for 1863 (issued 1864), pp. 612, 644. "Santa Barbara; Cat. Is., 20-60 fm.; common." Reprint in *Smithson. Mus. Coll.*, No. 252, 1872, pp. 98, 130. —Carpenter, *Proc. Calif. Acad. Sci.*, Vol. 3, February, 1866, p. 210. Coast of California. —Cooper, *Geol. Surv. Calif.*, *Geogr. Catalog. Moll.*, 1866, p. 12. "Santa Barbara 16-28 fms. Catalina I.?" —Sowerby, *Conch. Icon.*, Vol. 18, *Laeda*, November, 1871, sp. 56, pl. 9, fig. 56. "Hab. Catalina Islands." —Dall, *Proc. U. S. Nat. Mus.*, Vol. 24, 1902, p. 558, pl. 40, fig. 9. Near Catalina Island, California, in about 50 fathoms. —Arnold, *Mem. Calif. Acad. Sci.*, Vol. 3, 1903, p. 97, pl. 17, fig. 4. Pliocene at Deadman Island, San Pedro, California. Pleistocene of San Pedro and San Diego, California. Recent from Santa Barbara to Santa Catalina Island. —I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, no. 1, 1924, p. 23, pl. 6, fig. 4; pl. 37, fig. 5. "Type locality, Santa Barbara, California. Range: Puget Sound to Panama Bay. In the Pliocene and Pleistocene of California."

Nuculana hamata Carpenter, Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 125, pl. 1, figs. 14 and 15. Earlier records cited. Pleistocene and Recent.

Not *Zeuleda hamata* Marwick, *Proc. Malacol. Soc. London*, Vol. 16, no. 1, April, 1924, p. 25, figs. 1 and 2 (p. 26). "Locality. —Awatere Beds (Pliocene), east shore of Lake Grassmere, Marlborough, New Zealand."

Type Locality: Santa Barbara, California.

Range: Puget Sound to Panama Bay.

Collecting Station: Mexico: East of Cedros Island (126-D-12). 45 fathoms, crushed shell and mud bottom.

The shell of *Nuculana hamata* is extended into a long rostrum posteriorly which is squarely truncated at the end. The exterior of the shell is ornamented by strong concentric sculpture. The sculpture of the subspecies *Nuculana hamata limata* Dall⁵⁷ is very variable.

⁵⁷ *Leda hamata* Carpenter variety *limata* Dall, *Proc. U. S. Nat. Mus.*, Vol. 52, December 27, 1916, p. 397. "off Santa Rosa Island, California, in 50 fathoms." —I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 24 (as *Leda hamata limata*). Type locality cited. Range: Santa Barbara to San Diego, California.

Nuculana (Thestyleda) elaborata Prashad⁵⁸ described from the East Indies, is a similar species.

***Nuculana (Thestyleda) cordyla* Dall.**

Leda (Leda) cordyla Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 375, pl. 6, figs. 6 and 7. U. S. S. *Albatross* Station 3354, "Gulf of Panama, in 322 fathoms, mud, bottom temperature 46° F." Also at Station 2792, off Manta, Ecuador, in 401 fathoms.

Type Locality: Gulf of Panama, in 322 fathoms, mud. Type No. 122,915 U. S. Nat. Mus.

Range: Gulf of Panama to Manta, Ecuador, in deep water.

Shell, small, rostrate, with 14 anterior and 19 posterior hinge teeth. It is somewhat similar to *N. hamata*.

Subgenus ***Spinula*** Dall.

Spinula Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 377. "Type, *Leda calcar* Dall." —Thiele, *Handbuch syst. Weichtierkunde*, Teil 3, 1934, p. 789. *L. (S.) calcar* Dall, cited.

Type (by original designation): *Leda calcar* Dall.

Shell rostrate, acute behind, smooth, with a well-developed short amphidetic ligament, an internal resilium supported by triangular chondrophores, a defined lunule and escutcheon; a long, slender, completely united siphon, no papal tentacles; pallial sinus obsolete (Dall).

Ledaspina Marwick⁵⁹ from the Tertiary of New Zealand "differs from *Spinula* Dall in being almost equilateral and not drawn out posteriorly."

***Nuculana (Spinula) calcar* Dall.**

Leda (Spinula) calcar Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 378, pl. 10, figs. 1, 10. U. S. S. *Albatross* station 4658, "off the Peruvian coast, in S. Lat. 8° 30', W. Lon. 85° 36', in 2370 fathoms, green mud, bottom temperature 35° 3 F."

Type Locality: Off the coast of Peru, in Lat. 8° 30' S., Long. 85° 36' W., in 2370 fathoms, green mud. Type No. 110,573 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell compressed and acutely rostrate; posterior dorsal margin nearly straight, posterior end acutely angular, with a wide shallow sulcus below, setting off the rostrum.

***Nuculana (Spinula) calcarella* Dall.**

Leda (Spinula) calcarella Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 378. U. S. S. *Albatross* station 4656, "off the coast of Peru, in S. Lat. 6° 55' and W. Lon. 83° 34', in 2222 fathoms, green mud, bottom temperature 35° 2 F."

Type Locality: Off the coast of Peru, in Lat. 6° 55' S., Long. 83° 34' W., in 2,222 fathoms, green mud. Type No. 110,575 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell smaller than *Nuculana calcar* and near the base there are six or eight lines not coincident with the lines of growth.

⁵⁸ *Nuculana (Thestyleda) elaborata* Prashad, Siboga Exped., Monogr. 53c, Lamell., 1932, p. 22, pl. 1, figs. 32, 33, 34. "Holotype and an odd valve brought up in a deep-sea trawl at St. 52 (9° 3' 4 S., 119° 56' 7 E., 959 metres)."

⁵⁹ Marwick, J., *Geol. Surv. New Zealand, Palaeo. Bull.* No. 13, 1931, p. 53. "Type (original introduction): *Ledaspina stimulea* n. sp. Oligocene, New Zealand," p. 53, pl. 2, figs. 21, 24. From Loc. 1240 "Hungia mudstone, Island Creek, Tutamoe, S. D." Oligocene.

Subgenus *Jupiteria* Bellardi.

Jupiteria Bellardi, Mon. Nuculidi Terr. Terz. Piemonte e Liguria, 1875, p. 20.

———Dall, *Trans. Wagner Free Inst. Sci.*, Vol. 3, pt. 4, April, 1898, p. 579. "Type *L. concava* Bronn." ———Sacco, Moll. Terr. Terz. Piemonte e Liguria, Pt. 26, December, 1898, p. 56. "(Tipo *J. concava* (Brn.).)" ———Woodring, *Carnegie Inst. Washington, Publ.* 366, 1925, p. 18. Type: *Nucula concava* Bronn.

Type (designated by Dall): *Leda concava* Bronn. [= *Nucula concava* Bronn, Ital. Tert. Gebilde, 1831, p. 110. Italy. From "Ta. c." [= "Tabbiano, links zwischen Cg. und Parma" in the "Jüngerer Grobkalk, blau, thonig, in den Apenninen."]] ———Sacco, Moll. Terr. Terz. Piemonte e Liguria, Pt. 26, December, 1898, p. 56, pl. 12, figs. 1, 2, 3. Several localities in the Pliocene of Italy |.

Small corbuloid, strongly inflated shells; blunt and barely ridged rostrum; shallow sinus.

A few of the tropical west American species have been placed under *Jupiteria* by Dall but some of those are now believed to be referable to *Saccella*. It is probable however that some of the west American species may be referable to *Jupiteria*.

Jupiteria occurs in the Miocene and Pliocene of the Mediterranean region, in the Midway, early Tertiary of southeastern United States, and from Miocene to Recent in the Caribbean region. It has been recorded from the upper Eocene of California⁶⁰. Marwick & Finlay⁶¹ cited *Jupiteria* from the Danian, upper Cretaceous of New Zealand, Marwick⁶² cited it from the Medial Tertiary, and Powell⁶³ described a species which he referred to *Jupiteria*, from the waters of New Zealand.

An Australian species, "*Leda fortis*"⁶⁴, was believed by Hedley to be referable to *Jupiteria* but Iredale considered the species to belong to his genus *Terctileda*.

The subgeneric position of the following species of *Nuculana* is uncertain.

Nuculana acrita Dall.

Leda (Jupiteria) acrita Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 374. U. S. S. Albatross Station 2799, "Panama Bay, in 29½ fathoms, mud." Also other localities in Panama Bay, in 14-62 fathoms.

Type Locality: Panama Bay, in 29½ fathoms, mud. Type No. 110,690 U. S. Nat. Mus.

Range: Panama Bay.

Shell small, white, subequilateral, inflated and acutely rostrate posteriorly; hinge with about 15 anterior and 13 posterior teeth. Length, 6.2 mm.; height, 3.8 mm.; diameter, 3.0 mm.

Nuculana agapea Dall.

Leda (Jupiteria) agapea Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 373, pl. 6, figs. 4 and 5. U. S. S. Albatross station 3360, "Gulf of Panama, in 1672 fathoms, sand, bottom temperature 42°F." Also off the coast of Ecuador in 1573 fathoms.

⁶⁰*Jupiteria (Ledina) duttonae* Vokes, *Ann. New York Acad. Sci.*, Vol. 38, January 4, 1939, p. 44, pl. 1, fig. 6. From Loc. 1817 (Univ. Calif.), S. W. ¼ of N. W. ¼ of Sec. 15, T. 18 S., R. 14 E., 100 feet up the fourth small draw from west end of ridge; immediately opposite the place where Urruttia Canyon enters Salt Creek. Domengine formation, Eocene.

⁶¹Finlay, H. J., and Marwick, J., *Geol. Surv. New Zealand, Palaeo. Bull.* No. 15, 1937, p. 18.

⁶²Marwick, J., *Geol. Surv. New Zealand, Palaeo. Bull.* No. 13, 1931, pp. 51-53.

⁶³*Nuculana (Jupiteria) manawatawhia* Powell, *Discovery Repts.*, Vol. 15, 1937, p. 164, pl. 45, fig. 9. "Habitat: Off Three Kings Islands" New Zealand.

⁶⁴*Leda fortis* Hedley, *Rec. Australian Mus.*, Vol. 6, no. 5, July 18, 1907, p. 362, pl. 66, figs. 2 and 3. Dredged from 800 fathoms, 35 miles east of Sydney, Australia, in the Tasman Sea.

Type Locality: Gulf of Panama, in 1,672 fathoms, sand. Type No. 122,911 U. S. Nat. Mus.

Range: Gulf of Panama to coast of Ecuador, in deep water.

This species is most nearly related to *L. pontonia* Dall, but has the beaks more anterior and the sculpture coarser and more deeply incised (Dall).

***Nuculana bicostata* Sowerby.**

Laeda bicostata Sowerby, Conch. Icon., Vol. 18, *Laeda*, November, 1871, sp. 37, pl. 6, fig. 37. "*Hab. Panama.*"

Type Locality: Panama.

Range: Known only from the type locality.

Shell arched, semi-ovate, compressed, covered with a pale epidermis, sculptured with nearly concentric ridges undulated at the back and beaded on the ribs; anterior side roundly sub-acuminated with ventral margin roundly convex; posterior side rayed with two crenulated arched ribs, dorsal margin depressed, concave, acute at the end; umbos rounded, elevated (Reeve).

The arched form and distinct elevated and curved posterior ribs seem to distinguish this shell from the varieties of *Laeda elenensis*. (Reeve).

***Nuculana crispa* Hinds.**

Nucula crispa Hinds, *Proc. Zool. Soc. London*, December, 1843, p. 100. "*Hab. Gulf of Nicoya; from thirty-six fathoms.*" —Hinds, *Zool. Voy. Sulphur*, Moll., Pt. 3, 1844 [January, 1845 on cover], p. 64, pl. 18, fig. 14. Original locality cited.

Leda crispa Hinds, Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 134, pl. 229 (*Nuculidae*, pl. 4), figs. 107, 108. Gulf of Nicoya. —Sowerby, *Conch. Icon.*, Vol. 18, *Laeda*, November, 1871, sp. 55, pl. 9, fig. 55. "*Hab. Gulf of Nicoya.*"

Type Locality: Gulf of Nicoya, in 36 fathoms.

Range: Known only from the type locality.

The original illustration of this species shows a small rostrate form with strong concentric sculpture. There is a strong ridge on the rostrum and anterior to this is a narrowly elongate triangular depression separating the ridge from the remainder of the shell.

***Nuculana cuneata* Sowerby.**

Plate I, Figures 20 and 21.

Nucula cuneata Sowerby, *Proc. Zool. Soc. London*, 1832 (issued March 13, 1833), p. 198. "*Hab. ad Valparaiso.*" "Dredged in coarse sand and gravel, at various depths, from fourteen to forty-five fathoms." —Sowerby, *Conch. Illustr.*, *Nuculae*, 1833, p. 4, pl. 15, fig. 15. Valparaiso. New Guinea. —Reeve, *Conch. Syst.*, Vol. 1, 1841, p. 111, pl. 85, fig. 15. —Philippi, *Reise durch die Wueste Atacama*, 1860, pp. 176-177. Valparaiso; Papos, Chile.

Leda cuneata Sowerby, Hupé, *Hist. de Chile, Zool.*, Vol. 8, 1854, p. 307. "*Habita Valparaiso y otras partas de la República.*" —Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 128, pl. 228 (*Nuculidae*, pl. 3), figs. 92, 93. —Sowerby, *Conch. Icon.*, Vol. 18, *Laeda*, September, 1871, sp. 35, pl. 6, figs. 35a, 35b. "*Hab. Valparaiso, New Guinea.*"

Type Locality: Valparaiso, Chile, in from 14 to 45 fathoms, sand and gravel.

Range: Known with certainty only from the type locality.

Shell small, rostrate-ovate, with an ashy or greenish-olive periostracum, without conspicuous indented ray, and with concentric costellated sculpture.

Nuculana cuneata has been recorded from New Guinea but that record is believed to have been based on some similar but different species. According to Hanley⁶⁵, "*Leda inornata*" A. Adams⁶⁶, which was described from New Guinea, is identical with *Nuculana cuneata*. Dall (1909), however, considered *N. cuneata* to be identical with *N. acuta*.

***Nuculana excavata* Hinds.**

Nucula excavata Hinds, *Proc. Zool. Soc. London*, December, 1843, p. 100. "*Hab.* Panama; dredged among mud in thirty fathoms."——Hinds, *Zool. Voy. Sulphur*, Moll. Pt. 3, 1844 [January, 1845 on cover], p. 64, pl. 18, fig. 17. Original locality cited.

Leda excavata Hinds, Hanley, *Thes. Conch.*, Vol. 3, *Nuculidae*, 1860, p. 135, pl. 229 (*Nuculidae*, pl. 4), figs. 104, 105. Panama. ——Sowerby, *Conch. Icon.*, Vol. 18, *Laeda*, September, 1871, sp. 38, pl. 6, figs. 38a, 38b. "*Hab.* Panama."

Type Locality: Panama, in 30 fathoms, mud.

Range: Known only from the type locality.

The original illustration of this species shows an ovate-rostrate shell with a rostral ridge, anterior ray, and concentric sculpture.

***Nuculana hindsii* Hanley.**

Leda hindsii Hanley, *Proc. Zool. Soc. London*, 1860, p. 440. "*Hab.* Nicoyae fretum?" "Mr. Hinds referred this shell to his *Nucula crista*; it is very distinct, however, from the delineated type." ——Hanley, *Thes. Conch.*, Vol. 3, *Nuculidae*, 1860, p. 135, pl. 229 (*Nuculidae*, pl. 4), fig. 102. Gulf of Nicoya? ——Sowerby, *Conch. Icon.*, Vol. 18, *Laeda*, November, 1871, sp. 60, pl. 9, fig. 60. "*Hab.* Gulf of Nicoya?"

Type Locality: ? Gulf of Nicoya, Costa Rica.

Range: Known only from the type locality.

A small, pointed, ovate-oblong shell with a conspicuous anterior indented ray and fold, and with concentric sculpture.

***Nuculana lobula* Dall.**

Leda (Jupiteria) lobula Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 375. U. S. S. *Albatross* station 3422, "in 141 fathoms, mud, off Acapulco, Mexico, bottom temperature 53°.5."

Type Locality: Off Acapulco, Mexico, in 141 fathoms, mud.

Range: Known only from the type locality.

Shell small, olivaceous, oval with regular rounded concentric threads; hinge with about 13 anterior and 9 posterior teeth.

***Nuculana loshka* Dall.**

Leda (Leda) loshka Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 376, pl. 17, fig. 2. U. S. S. *Albatross* station 3392, "Gulf of Panama, in 1270 fathoms, hard bottom, temperature 36°.4 F."

Type Locality: Gulf of Panama, in 1,270 fathoms, hard bottom. Type No. 122,916 U. S. Nat. Mus.

⁶⁵ Hanley, S., *Thes. Conch.*, Vol. 3, *Nuculidae*, 1860, explanation to figs. 92 and 93, pl. 228 (*Nuculidae*, pl. 3).

⁶⁶ *Leda inornata* A. Adams, *Proc. Zool. Soc. London*, June 16, 1856, p. 48. "*Hab.* New Guinea. Mus. Cuming."

Range: Known only from the type locality.

Shell thin, very inequilateral and posteriorly produced in a long rostrum; disk smooth but under a lens showing fine concentric and a few irregular faint radial striations.

***Nuculana lucasana* Strong & Hertlein.**

Nuculana lucasana Strong & Hertlein, *Proc. Calif. Acad. Sci.*, Ser. 4, Vol. 22, no. 6, December 31, 1937, p. 160, pl. 34, figs. 9, 12, 13. "Lat. 23° 03' to 23° 06' N., Long. 109° 36' to 109° 31' W., dredged about 10 miles due east of San Jose del Cabo, Lower California, Mexico, in 20 to 220 fathoms."

Type Locality: East of San Jose del Cabo, Lower California, Mexico, in 20 to 220 fathoms. Type No. 6966 Calif. Acad. Sci. Paleo. Type Coll.

Range: Known only from the type locality.

Shell differing from *Nuculana lobula* Dall in the greater diameter in proportion to the height, and in the presence of an anterior radial depression, a feature not mentioned in the original description of Dall's species.

***Nuculana ornata* d'Orbigny.**

Leda ornata d'Orbigny, Voy. Amér. Mérid., Vol. 5, 1846, p. 546, pl. 82, figs. 4-6. "rencontrée dans du sable de fond, recueilli à Payta (Pérou)." —Hanley, *Thes. Conch.*, Vol. 3, *Nuculidae*, p. 128, pl. 228 (*Nuculidae*, pl. 3), figs. 97, 98. Payta, Peru. —Sowerby, *Conch. Icon.*, Vol. 18, *Laeda*, September, 1871, sp. 36, pl. 6, figs. 36a, 36b, "*Hab.* Payta, Peru." —Wolf, *Geogr. & Geol. Ecuador* (Leipzig), 1892, p. 631. Pliocene of Umbí, Ecuador. Recent in region about Paíta, Peru. —Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 251. Paíta, Peru.

Type Locality: Paíta, Peru, sand.

Range: Known only from the type locality.

Shell ovate-elongate, rostrate, subventricose, with fine even concentric sculpture and a strong indented anterior ray.

***Nuculana oxia* Dall.**

Leda oxia Dall, *Proc. U. S. Nat. Mus.*, Vol. 52, December 27, 1916, p. 395. "Station 2901, off Santa Rosa Island, California, in 48 fathoms, muddy bottom." —Dall, *U. S. Nat. Mus.*, Bull. 112, 1921, p. 11. Santa Rosa Island, California, to the Gulf of California. —I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 18. Type locality and range same as cited by Dall. —E. K. Jordan, *Proc. Calif. Acad. Sci.*, Ser. 4, Vol. 15, no. 7, 1926, p. 244. San Quintin, Lower California; Pleistocene.

Nuculana oxia Dall, Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 125. Earlier records cited. —Keen, *Check List West North Amer. Mar. Moll.* (Stanford Univ. Press), 1937, p. 23. Lat. 23°-34°N.

Type Locality: Off Santa Rosa Island, California, in 48 fathoms, mud. Type No. 214,448 U. S. Nat. Mus.

Range: Santa Rosa Island, California, to the Gulf of California.

Shell minute, very acute posteriorly, beaks subcentral; sculpture of regular equal concentric ridges with subequal interspaces; a depressed ray from beak to base anteriorly; hinge with about eight teeth on either side of the resilifer.

***Nuculana peruviana* Dall.**

Leda (Leda) peruviana Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 377. "dredged in 1036 fathoms, mud, off Aguja Point, Peru, at station 4654."

Type Locality: Off Aguja Point, Peru, in 1,036 fathoms, mud.

Range: Known only from the type locality.

Shell large, slender, rostrate; surface mostly smooth but with a few coarse irregular wrinkles on basal half of disk anteriorly; hinge with about 15 anterior and 38 posterior teeth.

***Nuculana pontonia* Dall.**

Leda pontonia Dall, *Proc. U. S. Nat. Mus.*, Vol. 12, 1889, p. 257, pl. 13, figs. 5, 5b. "Stations 2807, and 2808, in 812 and 634 fathoms, mud and sand, near the Galapagos Islands, Pacific Ocean; temperatures 38°.4 and 40°F." —Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 12. Santa Barbara Islands, California, to Peru and the Galapagos Islands, in deep water. —I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 20, pl. 1, figs. 4 and 5. Locality and range same as cited by Dall. —Heath, *Mem. Mus. Roy. d'Hist. Nat. Belg.*, Ser. 2, Fasc. 10, 1937, pp. 5, 17, 20. Off San Diego, California, in 822 fathoms.

Leda (Jupiteria) pontonia Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 374. Off Galapagos Islands; Gulf of Panama; off San Diego, California; in 634 to 1672 fathoms.

Type Locality: Near the Galapagos Islands, in 634-812 fathoms, mud and sand.

Range: Santa Barbara Islands, California, to Peru, and the Galapagos Islands, in deep water.

Shell stout, strong, inflated with recurved pointed, posterior end; concentric sculpture of fine regular threads which become obsolete on the umbos; hinge with 16 anterior and 13 posterior teeth.

***Nuculana rhytida* Dall.**

Leda (Leda) rhytida Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 376. U. S. S. *Albatross* station 3422, "off Acapulco, Mexico, in 141 fathoms, mud, bottom temperature 53°.5 F."

Type Locality: Off Acapulco, Mexico, in 141 fathoms, mud. Type No. 122,918 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell small, elongate-ovate, translucent white, with olive-gray periostracum; posteriorly attenuated but not acute; sculpture of concentric riblets which become obsolete on upper posterior portion of shell; hinge with 11 anterior and nine posterior teeth.

Genus *Adrana* H. & A. Adams.

Adrana H. & A. Adams, *Gen. Rec. Shells*, Vol. 2, 1858, p. 547. —Stoliczka, *Mem. Geol. Surv. India. Palaeont. Indica. Cret. Fauna South India*, Vol. 3, 1871, p. 320. "Type Nuc. [*Adrana*] *lanceolata*, Lam."

Type (designated by Stoliczka): *Nucula lanceolata* Lamarck. [Anim. s. Vert., Vol. 6, 1819, p. 58. No locality cited. According to d'Orbigny (Voy. Amér. Mérid., Vol. 5, 1846, p. 545), "Le véritable *N. lanceolata* de Lamarck est propre à la Nouvelle-Hollande." According to Hanley (Thes. Conch., Vol. 3, 1860, explanation to pl. 227 (*Nuculidae*, pl. 2, fig. 35) it is *Leda taylori* from Guatemala. Chenu (Man. de Conchyl., Vol. 1, 1862, p. 180, fig. 904) gave an illustration of a shell cited as "*A. lanceolata*, Lamarck," but no locality was cited. The figure given by Chenu and the same figure given by Tryon but cited as *Leda (Adrana) sowerbyana* (Struct. and Syst. Conch., Vol. 3, 1884, pp. 249, 443, pl. 126, fig. 32. "*Xipixapi*") somewhat resembles

that of *Adrana electa* A. Adams (*Proc. Zool. Soc. London*, 1856, p. 48 (as *Leda electa*) "*Hab. Santos, Brazil (Capt. Martin). Mus. Cuming.*" ——— Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 109, pl. 227 (*Nuculidae*, pl. 2), figs. 40, 41 (as *Leda electa*). Santos, Brazil. ——— Sowerby, *Conch. Icon.*, Vol. 18, *Laeda*, February, 1871, sp. 2, pl. 1, figs. 2a, 2b. "*Hab. Santos, Brazil*"), and so also does that of G. B. Sowerby cited as *Nucula lanceolata* Lamarck (*Gen. Shells*, pl. 102, fig. 1, which Hanley referred to *Leda electa*), and that of G. B. Sowerby II cited as *Laeda sowerbyana* (*Conch. Icon.*, Vol. 18, *Laeda*, pl. 1, fig. 1a)].

The shells referred to this genus are very elongate, lanceolate, and often have nearly straight dorsal margins, the beaks scarcely projecting; the sculpture is fine and composed of concentric or somewhat oblique riblets.

Nine species of *Adrana* have been described from tropical west American waters. Three of these, *Adrana elongata* Sowerby, *A. sowerbyana* d'Orbigny and *A. suprema* Pilsbry & Olsson, have large shells with a nearly straight dorsal border. The others are smaller and the dorsal border slopes somewhat in each direction from the beak. No species of *Adrana* has been described from the Tertiary of western North America but several have been recorded from Eocene⁶⁷ to Recent in the southeastern part of the United States and from Miocene⁶⁸ to Recent in the Caribbean region. The genus has been recorded from the Oligocene of Peru. At the present time the genus *Adrana* appears to be entirely confined to the New World. One Recent species "*Leda metacalfi*," cited from the Philippine Islands by Hanley and by Sowerby was originally described without information as to locality. We have not noticed it cited in the literature as present in recent collections from the Philippine Islands.

KEY TO THE SPECIES OF *Adrana*.

- A. Anterior and posterior dorsal margins forming a nearly straight line
 - a. Umbos a little anterior to the center
 - b. Ventral margin scarcely concave toward ends *elongata*
 - bb. Ventral margin distinctly concave toward ends producing more attenuate terminations *sowerbyana*
 - aa. Umbos central *suprema*
- B. Anterior and posterior dorsal margins forming an obtuse angle at the umbos
 - a. Beaks nearly central
 - b. Branching riblets on anterior dorsal area *tomosiana*
 - bb. Anterior dorsal area without branching riblets *arcuata*
 - aa. Beaks slightly anterior to center
 - c. Surface fully sculptured
 - d. Anterior ventral margin narrowly constricted *taylori*
 - dd. Anterior ventral margin not constricted *crenifera*
 - cc. Posterior dorsal area smooth
 - e. Concentric sculpture of coarse riblets *exoptata*
 - ee. Concentric sculpture fine *penascoensis*

⁶⁷ *Adrana aldrichiana* Harris, *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 47, April 9, 1895, p. 47, pl. 1, fig. 6 (under the genus *Leda*). "Brazos River, Tex., one and one-half miles below Mosley's Ferry." "Lower Claiborne. Eocene." ——— Harris, *Bull. Amer. Paleol.*, Vol. 6, No. 31, June 30, 1919, p. 71, pl. 25, figs. 20, 21.

⁶⁸ See Olsson, A. A., *Bull. Amer. Paleol.*, Vol. 9, Bull. No. 39, 1922, pp. 346-347 (174-175). ——— Maury, *Serv. Geol. e Miner. Brazil, Monogr.* 4, 1924, p. 405. ——— Mansfield, *Florida State Geol. Surv., Bull.* No. 8, 1932, p. 36.

***Adrana arcuata* Sowerby.**

Laeda arcuata Sowerby, Conch. Icon., Vol. 18, *Laeda*, September, 1871, sp. 20, pl. 4, fig. 20. "Hab.?"

Nuculana arcuata Sowerby, Pilsbry & Olsson, *Nautilus*, Vol. 48, no. 4, 1935, p. 118, pl. 6, figs. 2 and 3. Point Ancon, Santa Elena, Ecuador. Also Ecuadorian and Peruvian coasts.

Type Locality: Not originally cited. Point Ancon, Santa Elena, Ecuador, here designated as type locality.

Range: Coasts of Ecuador and Peru.

Shell elongate with arcuate ventral margin; ornamentation of regular thread-like ribs over the entire surface.

***Adrana crenifera* Sowerby.**

Nucula crenifera Sowerby, *Proc. Zool. Soc. London*, 1832 (issued March 13, 1833), p. 197. "Hab. ad Xipixapi." "It was dredged in sandy mud, at a depth of nine fathoms." —Sowerby, Conch. Illustr., *Nucular*, 1833, pp. 3, 6, pl. 14, fig. 3. "Xipixapi, Mr. Cuming." —Reeve, Conch. Syst., Vol. 1, 1841, p. 110, pl. 84, fig. 1. —Hanley, Cat. Rec. Biv. Shells, p. 167, 1843, p. 376, 1856?, Suppl. 19, fig. 51, 1846. Xipixapi.

Leda crenifera Sowerby, Hanley, Thes. Conch., Vol. 3, *Leda*, 1860, p. 110, pl. 227 (*Nuculidae*, pl. 2), figs. 37 and 38. Xipixapi. —Sowerby, Conch. Icon., Vol. 18, *Laeda*, September, 1871, sp. 21, pl. 4, figs. 21a, 21b. "Hab. Xipixapi."

Yoldia (Adrana) crenifera Sowerby, Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 251. Jipijapa, Ecuador.

Type Locality: Xipixapi, Ecuador, in 9 fathoms, sandy mud.

Range: Known only from the type locality.

Transversely elongated, lanceolate, smooth, with very fine transverse striae, the dorsal margin carinated, the keel crenulated (Hanley).

Adrana janeiroensis E. A. Smith⁶⁹ from off Rio de Janeiro, Brazil, bears some resemblance to *A. crenifera*. A species of *Adrana* somewhat similar to *A. crenifera* has been mentioned by Olsson⁷⁰ as occurring in the Oligocene of Peru, and a species compared to *A. crenifera* was cited by Wolf⁷¹ from the Pliocene of Ecuador. "*Nucula dorbignyi*" described by Philippi⁷² from the Tertiary of Chile was compared to *Adrana crenifera*.

The species "*Leda metcalfi*" Hanley is very similar if not identical with *A. crenifera*. It was described by Hanley⁷³ without locality information. Later, Hanley⁷⁴ cited it from the Philippine Islands as did Sowerby⁷⁵. Except for citation of the species in the paper by Faustino⁷⁶ we have not noticed a record of it from the Philippine Islands in any recent papers on the fauna of that region.

⁶⁹ *Adrana janeiroensis* E. A. Smith, Brit. Mus. (Nat. Hist.) Brit. Ant. ("Terra Nova") Exped., 1910. Nat. Hist. Rept. Zool., Vol. 2, no. 4, Moll. pt. 1, p. 98, pl. 2, fig. 16, 1913. "Off Rio de Janeiro in 40 fathoms. Lat. 22° 56' S., Long. 41° 34' W."

⁷⁰ Olsson, A. A., *Bull. Amer. Paleol.*, Vol. 17, no. 63, 1931, p. 134 (38).

⁷¹ Wolf, T., *Geogr. & Geol. Ecuador*, (Leipzig), 1892, p. 631. Pliocene of Uimbi, Ecuador.

⁷² *Nucula dorbignyi* Philippi, *Los Fos. Terc. i. Cuart. Chile*, 1887, p. 188, pl. 41, fig. 10. "Es de Levu i está sobre un gran pedazo de roca dura."

⁷³ Hanley, S., *Proc. Zool. Soc. London*, 1860, p. 370. "Hab. ———?"

⁷⁴ Hanley, S., *Thes. Conch.*, Vol. 3, 1860, expl. to pl. 227 (*Nuculidae*, pl. 2), fig. 34.

⁷⁵ Sowerby, II, G. B., *Conch. Icon.*, Vol. 18, *Laeda*, September, 1871, sp. 18, pl. 4, fig. 18.

⁷⁶ Faustino, L. A., *Bur. Sci. Philippine Islands, Monogr.* 25, October 30, 1928, p. 18.

***Adrana elongata* Sowerby.**

Plate II, Figure 16.

Nucula elongata Sowerby, *Proc. Zool. Soc. London*, 1832 (issued March 13, 1833), p. 197. "Hab. in Columbia Occidentali." "Dredged in sandy mud, at a depth of twelve fathoms, at Xipixapi." —Sowerby, *Conch. Illustr., Nuculae*, 1833, pp. 3, 6, pl. 14, fig. 2. "Salango, Mr. Cuming." —Müller, *Synop. Test. Viv.*, 1836, p. 190. Original record cited. —Reeve, *Conch. Syst.*, Vol. 1, 1841, p. 110, pl. 84, fig. 2. —Catlow & Reeve, *Conch. Nomencl.*, 1845, p. 53. —Hanley, *Cat. Rec. Bivalve Shells*, p. 167, 1843, p. 376, ?1856, Suppl. pl. 19, fig. 50, 1846. [Not accurate figure.]. West Colombia. —d'Orbigny, *Voy. Amér. Mérid.*, Vol. 5, 1846, p. 545. Original record cited.

Leda elongata Sowerby, Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 106, pl. 227 (*Nuculidae*, pl. 2), fig. 39. "Salango, W. Columbia." —Sowerby, *Conch. Icon.*, Vol. 18, *Lueda*, 1871, sp. 4, pl. 1, fig. 4. "Hab. Salango, West Columbia."

Not *Leda elongata* Treat, *Ann. de Paleol.*, Vol. 22, fasc. 2, 1933, p. 52, pl. 6, fig. 3. "Environs d'Ankito hazo; niveau inférieur." Madagascar. Permo-Triassic.

Yoldia (Adrana) elongata Sowerby, Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 251. Coast of Ecuador. —Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 51. Zoogeographical province of Panama.

Nuculana (Adrana) sowerbyana d'Orbigny, Strong, Hanna & Hertlein, *Proc. Calif. Acad. Sci.*, Ser. 4, Vol. 21, no. 10, 1933, p. 118. Acapulco, Mexico.

Not *Nucula (Adrana) sowerbyana* d'Orbigny.

Type Locality: Xipixapi, Ecuador, in 12 fathoms, sandy mud.

Range: Acapulco, Mexico, to Ecuador.

Collecting Stations: Guatemala: 7 miles west of Champerico (197-D-1). 14 fathoms, mud bottom; El Salvador: La Libertad (198-D-2). 14 fathoms, mud bottom.

Specimens from three localities appear referable to *Adrana elongata* Sowerby. The application of the specific name *elongata* to this species is somewhat unfortunate because the species is not as elongate in form as is *Adrana sowerbyana*, a similar species. The beaks are more central and the ends much less tapering on *A. elongata* than is the case in *A. sowerbyana*. Another large species of the genus is *Adrana suprema* Pilsbry & Olsson with a length of 107 mm. It differs from *A. elongata* Sowerby in that the beaks are nearly central rather than somewhat anterior as in the species described by Sowerby.

***Adrana exoptata* Pilsbry & Lowe.**

Plate II, Figure 11.

Leda (Adrana) exoptata Pilsbry & Lowe, *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 84, p. 107, pl. 17, figs. 8 and 9, May 21, 1932. "Mexico: Guaymas, 20 fathoms."

Type Locality: Guaymas, Mexico, in 20 fathoms. Type No. 155633 Acad. Nat. Sci. Philadelphia.

Range: Guaymas, Sonora, Mexico, to Tangola-Tangola, Oaxaca, Mexico.

Collecting Stations: Mexico: 4 miles south-southwest of Maldonado Point (192-D-1). 26 fathoms, mud bottom; Santa Cruz Bay (195-D-21). 18 fathoms, mud bottom; Tangola-Tangola Bay (196-D-17). 4 fathoms, sand bottom.

The shell of this elongate form possesses a smooth band anterior to the posterior carina. The concentric sculpture on the anterior part of the shell becomes obsolete and grades into the smooth area. Some of the specimens in the present collection are slightly upturned at the posterior ex-

tremity of the shells but others barely show this feature and seem to agree almost exactly with *Adrana exoptata* Pilsbry & Lowe. *Adrana newcombi* Angas⁷⁷ described from the east side of the isthmus of Panama appears to be a very similar species.

***Adrana penascoensis* Lowe.**

[?] *Yoldia* apparently *electa* A. Adams, Dall, *Amer. Jour. Conch.*, Vol. 7, no. 2, November 2, 1871, p. 154. From the head of the Gulf of California.

Leda (*Yoldia*) *lanceolata* Lamarck, Stearns, *Proc. U. S. Nat. Mus.*, Vol. 17 1894, p. 147. Gulf of California.

Leda (*Adrana*) *penascoensis* Lowe, *Trans. San Diego Soc. Nat. Hist.*, Vol. 8, no. 6, March 21, 1935, p. 18, pl. 1, fig. 8. "Punta Peñasco, Sonora, dredged 10 fathoms."

Type Locality: Punta Peñasco, Sonora, Mexico, in 10 fathoms. Type No. 11393 Lowe Coll. in San Diego Soc. Nat. Hist.

Range: Gulf of California.

Shell white, with a straw-colored glossy periostracum; strongly compressed beaks much nearer the anterior end. Dorsal line nearly straight, ventral margin curved, anterior and posterior ends about equally angular. Dorsal edges of both valves slightly crenate the entire length. Sculpture of fine concentric lines of growth over the entire surface of both valves, except a narrow portion bordering the posterior dorsal margin, which is entirely smooth. Diameter 37.5 mm., altitude 9.4 mm. (Lowe).

***Adrana sowerbyana* d'Orbigny.**

Nucula lanceolata Lamarck, Sowerby, *Conch. Illustr.*, *Nuculae*, 1833, p. 3, pl. 14, fig. 1. "Xipixapi." —Deshayes, ed. of Lamarck's *Anim. s. Vert.*, Vol. 6, 1835, p. 504. [No locality cited]. —Reeve, *Conch. Syst.*, Vol. 1, 1841, p. 110, pl. 84, fig. 1. —Hanley, *Cat. Bivalve Shells*, Suppl. pl. 19, fig. 49, 1846.

Not *Nucula lanceolata* J. Sowerby, *Miner. Conch.*, Vol. 2, 1817, p. 178, pl. 180, fig. 1. "At Bawdsey, Suffolk, in Crag."

Not *Nucula lanceolata* Lamarck, *Anim. s. Vert.*, February-June, 1819, p. 58. "Habite"

Leda sowerbyana d'Orbigny, *Voy. Amér. Mérid.*, Vol. 5, 1846, p. 544. Reference cited "*Nucula lanceolata*, Sow., 1831, *Gen. of Shells*, no. 17, fig. 1 (non *Lanceolata*, Lamk., 1819)." "Elle a été pêchée par M. Cuming à la côte de Xipixapi, république de l'Équateur."

[?] *Nucula elongata* Sowerby, Valenciennes, *Voy. Venus, Zool.*, Moll., 1846, pl. 23, fig. 4 (two figs.).

Leda sowerbyana d'Orbigny, Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 107, pl. 227 (*Nuculidae*, pl. 2), fig. 33. Xipixapi.

Laeda sowerbyana d'Orbigny, Sowerby, *Conch. Icon.*, Vol. 18, *Laeda*, November, 1871, sp. 1, pl. 1, fig. 1b (only). "Hab. Xipixapi."

Yoldia (*Adrana*) *sowerbyana* d'Orbigny, Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 251. "Jipijapa, Ecuador." —Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 51. Panamanian zoogeographical province.

Type Locality: Xipixapi, Ecuador.

Range: Panama to Ecuador.

A few specimens in the collection appear to be intermediate between *Adrana sowerbyana* and *A. elongata*. The shell of *Adrana sowerbyana* d'Orbigny is similar to *Adrana elongata* Sowerby but is narrower and with more tapering extremities. Hanley believed that the specimen figured by

⁷⁷ *Leda* (*Adrana*) *newcombi* Angas, *Proc. Zool. Soc. London*, March 5, 1878, p. 314, pl. 18, figs. 16, 17. "Hab. Dredged in Navy Bay, Aspinwall, in 8 fathoms."

Valenciennes as "*Nucula elongata*" Sowerby might probably be referred to *sowerbyana*. The figure given by Valenciennes is somewhat less tapered at the ends than *sowerbyana* but otherwise it is quite similar. Stearns cited *Adrana sowerbyana* (as *L. lanceolata*) from the Gulf of California but Lowe described *Adrana penascoensis* from that region and Pilsbry & Lowe in discussing *Adrana exoptata* stated that *A. elongata* and *A. sowerbyana* occur much further south. *A. scaphoides* Rehder⁷⁸ from eastern Colombia is a similar species.

The name *Adrana sowerbyana* presents some complications in regard to nomenclature. *Nucula lanceolata* J. Sowerby was originally described as a fossil from the Pliocene of England in 1817. Lamarck also described under the same name in 1819, a Recent shell without locality information. G. B. Sowerby in the Genera of Shells (No. 17, 1825, pl. 102, fig. 1) illustrated a species under the name of *Nucula lanceolata* Lamarck but without information as to locality, while in 1833 G. B. Sowerby Jr. (Conch. Illustr., Nuculae, p. 3, pl. 14, fig. 1) illustrated a shell as *Nucula lanceolata* Lamarck with the locality as Xipixapi, which is in western Colombia, and also cited a reference to the figure in the Genera of Shells. d'Orbigny in 1846 noticed that the name *Nucula lanceolata* of Lamarck was preoccupied by the same combination of names used by J. Sowerby, hence d'Orbigny proposed for Lamarck's species the new name *Leda sowerbyana* and stated that it was collected at Xipixapi by Cuming. This evidently refers to the shell and locality in Conchological Illustrations although in the synonymy d'Orbigny cited the reference to the illustration in the Genera of Shells. Hanley in 1860 described "*Leda*" *taylori* from Guatemala and in the synonymy cited the reference to *Nucula lanceolata* of Lamarck and to the figure of *Nucula lanceolata* given by Sowerby in the Conchological Illustrations while the illustration of *N. lanceolata* in the Genera of Shells is referred by Hanley to *Leda electa* A. Adams from Brazil. Sowerby in 1871 referred the illustration, of *N. lanceolata* Lamarck in the Genera of Shells to "*Leda*" *sowerbyana*.

Although d'Orbigny stated that the true *Nucula lanceolata* Lamarck came from New Holland, it does not appear to have been recognized subsequently in that region. The figure in the Genera of Shells, which has a distinctly curved anterior dorsal margin and rounded anterior ventral margin, appears to be distinct from the one in the Conchological Illustrations which has an almost straight dorsal margin and is attenuated at both ends. We therefore follow Hanley in referring this figure (1833) to the west American *sowerbyana* while the one in the Genera of Shells (1825) may be referred to the east American "*Leda*" *electa* A. Adams.

"*Nucula darwini*"⁷⁹ described by Philippi from the Tertiary of Chile was compared to "*N. lanceolata* Sow."

***Adrana suprema* Pilsbry & Olsson.**

Nuculana (*Adrana*) *suprema* Pilsbry & Olsson, *Nautilus*, Vol. 48, no. 4, April, 1935, p. 117, pl. 6, fig. 1. "Beach between Port Guanico and the mouth of the Guanico river, Los Santos province, Panama."

Type Locality: Beach between Port Guanico and the mouth of the Guanico river, Los Santos province, Panama.

Range: Known only from the type locality.

Shell resembling *Adrana elongata* but with the beaks nearly central.

⁷⁸*Adrana scaphoides* Rehder, *Nautilus*, Vol. 53, no. 1, July, 1939, p. 17, pl. 6, fig. 5. "Near Cartagena, Colombia."

⁷⁹*Nucula darwini* Philippi, Los Fos. Terc. i Cuart. Chile, 1887, p. 188, pl. 41, fig. 17. From same locality as *Nucula darwini*, that is, "Es de Levu i está sobre un gran pedazo de roca dura."

***Adrana taylori* Hanley.**

Leda taylori Hanley, *Proc. Zool. Soc. London*, 1860, p. 370. "Hab. Guatemala."
 —Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 109, pl. 227 (*Nuculidae*, pl. 2), fig. 35. "Guatemala." —Sowerby, *Conch. Icon.*, Vol. 18, *Laeda*, September, 1871, sp. 17, pl. 4, fig. 17. "Hab. Guatemala."

Type Locality: Guatemala.

Range: Known only from the type locality.

Sowerby (1871) in discussing *Adrana arcuata* stated that "In *Leda taylori*, which resembles this species, there is peculiar narrowness and almost a constriction in the ventral margin at the anterior end not observable in *Laeda arcuata*." *Adrana taylori* is similar to *A. crenifera* Sowerby and *A. electa* A. Adams⁸⁰.

***Adrana tonosiana* Pilsbry & Olsson.**

Plate II, Figure 15.

Nuculana (Adrana) tonosiana Pilsbry & Olsson, *Nautilus*, Vol. 48, no. 4, April, 1935, p. 117, pl. 6, fig. 4. "Estero Bucaru, mouth of the Tonosi River, Los Santos, Panamá."

Type Locality: Estero Bucaru, Mouth of Tonosi River, Los Santos Province, Panama. Type No. 164025 Acad. Nat. Sci. Philadelphia.

Range: Off Mazatlan, Sinaloa, Mexico, to Panama.

Collecting Stations: Guatemala: 7 miles west of Champerico (197-D-1-2). 14 fathoms, mud bottom; El Salvador: La Libertad (198-D-1-2). 13-14 fathoms, mud bottom; Nicaragua: Corinto (200-D-19). 12-13 fathoms, mangrove leaves on bottom; Panama: Gulf of Chiriqui (221-D-1-5). 35-40 fathoms, sandy mud bottom.

A large series of specimens dredged off Central America have been referred to *Adrana tonosiana* Pilsbry & Olsson. There seems but little difference between these and young *Adrana arcuata* Sowerby. According to Pilsbry & Olsson *tonosiana* is a smaller form, their specimens not exceeding 26 mm. Some of the specimens in the present collection attain a length of 33 mm. We have assigned these to *tonosiana* chiefly due to the strong and sometimes branching ribbing on the anterior dorsal margin. This was considered by Pilsbry & Olsson to be a characteristic feature of *tonosiana* and not present on *A. arcuata* Sowerby. If this is constantly absent on *A. arcuata* it would seem best to leave *tonosiana* as a valid species, otherwise they are extremely similar. A few irregular radial striae are present on the exterior of the shells in the present collection but these were not mentioned in the description of Pilsbry & Olsson. A single somewhat worn right valve from Sta. 221-D-1-5 has also been assigned to *A. tonosiana* because of the branching ribbing on the anterior dorsal edge. The shell is larger than the type of *A. tonosiana* and has a more pointed posterior end.

Adrana crenifera Sowerby is somewhat similar in form but the dorsal margin has a greater slope from the beak and the edge of the posterior ridge is said to be angular and decidedly crenulated.

Genus *Yoldia* Möller.

Yoldia Möller, *Naturhist. Tidsskrift*, IV (1), 1842, p. 91, also *Index Moll. Groenlandiae*, 1842, p. 18. Species cited: "*Y. arctica*, *Nucula arctica* Gray" and "*Y. angularis* nob., *Nuc. myalis* Couth.?" —S. A. Miller, *North Amer. Geol. and Palaeo.*, (Cincinnati, Ohio), 1889, p. 516. "Type *Y. myalis*," fig. 935.

⁸⁰ *Leda electa* A. Adams, See Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 109, pl. 227 (*Nuculidae*, pl. 2), figs. 40 and 41. "Santos, Brazil." —Sowerby, *Conch. Icon.*, Vol. 18, *Laeda*, February, 1871, sp. 2, pl. 1, figs. 2a, 2b. "Hab. Santos Brazil."

———Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, June 15, 1898, p. 858. "Type. ———*Yoldia hyperborea* Torrell=*Yoldia arctica* Möller (not Gray)." ———Cossmann, *Act. Soc. Linn. Bordeaux*, Vol. 66 (Conch. Neog. Aquit., Vol. 2, Livr. 1), 1912, p. 113. Genotype: *L. hyperborea* Loven. ———Gardner, *Geol. Surv. Maryland*, Upper Cretaceous, 1916, p. 518. "Type. ———*Yoldia arctica* Gray." ———Woodring, *Carnegie Inst. Washington, Publ.* 366, 1925, p. 21. Type: "*Nucula arctica* Möller not Gray (= *Nucula myalis* Couthouy)." ———Stewart, *Acad. Nat. Sci. Philadelphia, Spec. Publ.* No. 3, 1930, p. 59. Type designation of Verrill & Bush accepted. ———Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 126. Type: *Nucula arctica* Gray.

Type (designated by Gardner): *Nucula arctica* Gray. [Suppl. to Ap. Parry's First Voy., 1819-1820, p. 241, 1824. ———Also illustrated by Grant & Gale, *Mem. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, pl. 1, figs. 10, 11 (figures copied from Mossewich, *Acad. Sci. Union Republ. Soviet Socialist.*, Livr. 19, 1928, pl. 1, figs. 1 and 3). Circumboreal].

Somewhat similar to *Nuculana* but with thinner, subovate shell, slightly rostrate, usually gaping posteriorly; exteriorly sculptured by growth-lines or concentric striae; hinge consisting of two subequal series of small chevron-shaped teeth; resilium-pit large, symmetrically underlapping both rows of teeth; pallial sinus deep and wide, the apex broadly U-shaped.

There is considerable disagreement among various authors as to the designation of the type species of *Yoldia*. Grant & Gale have given a discussion of the problem. The designation of *Yoldia myalis* Couthouy by Miller in 1889 is not strictly valid due to the fact that in the original list of species under *Yoldia* it was cited as "*Nuc. myalis* Couth." and is thus a *species inquirenda* and not acceptable under the present rules of nomenclature. The interpretation of the type of *Yoldia* as indicated by Grant & Gale appears to be the correct one, and the type here accepted is *Nucula arctica* Gray. *Yoldia* probably ranges from Eocene to Recent, although it has been recorded from the Carboniferous. Several species of the genus *Yoldia* have been described from the Eocene of Western North America.

Microyoldia Verrill & Bush¹, with the type *M. regularis* Verrill, has not been recorded from tropical west American waters.

Subgenus **Katadesmia** Dall.

Katadesmia Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1898, p. 379. Sole species: *Yoldia* (*Katadesmia*) *vincula* Dall. ———Thiele, *Handbuch Syst. Weichtierkunde*, Teil 3, 1934, p. 790. *Y. (K.) vincula* Dall, cited.

Type (by original designation and by monotypy): *Yoldia* (*Katadesmia*) *vincula* Dall.

Southern species with well-defined functional opisthodetic ligament.

***Yoldia* (*Katadesmia*) *vincula* Dall.**

Yoldia (*Katadesmia*) *vincula* Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 379, pl. 5, fig. 5. U. S. S. *Albatross* station 3360, "in 1672 fathoms, sand, Gulf of Panama, bottom temperature 42° F." Also at stations 3354 and 3361, in 322 fathoms, and in 1471 fathoms.

Yoldia vincula Dall, Zetek, *Rev. Nueva*, Nos. 1 & 2, 1918, p. 38. Panama.

Type Locality: Gulf of Panama, in 1,672 fathoms, sand. Type No. 122,903 U. S. Nat. Mus.

Range: Gulf of Panama.

¹*Microyoldia* Verrill & Bush, *Amer. Jour. Sci.*, Ser. 4, Vol. 3, January, 1897, p. 56. "Type *M. regularis* (V.)," figs. 5 and 6 (p. 60). ———Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, 1898, p. 860. Type: *Microyoldia regularis* Verrill, p. 860, pl. 78, figs. 5 and 6.

The species is notable for its pale color and brilliant polish (Dall). Shell with the general form of *Sanguinolaria rosea*; hinge with 15 anterior and about 25 posterior teeth.

Subgenus **Megayoldia** Verrill & Bush.

Megayoldia Verrill & Bush, *Amer. Jour. Sci.*, Ser. 4, Vol. 3, January, 1897, p. 55. "Type *M. thraciaeformis* (Storer)," fig. 17. —Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, 1898, p. 859. Type: *Megayoldia thraciaeformis* (Storer).

Type (by original designation): *Megayoldia thraciaeformis* (Storer). [= *Leda thraciaeformis* Storer, *Boston Jour. Nat. Hist.*, Vol. 2, 1838, p. 122, text fig. ". . . from the stomach of a Platessa —the dentata of Mitchell —called by our fishermen, *Sand dab*: —this fish was caught off Provincetown, Cape Cod, in about thirty fathoms of water." —I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 27, pl. 5, fig. 1. Arctic Ocean to Oregon and Puget Sound. Also Atlantic].

Broad, compressed form, with a very blunt, indefinite, postero-dorsal rostrum, and with a low radial ridge, ending in a postero-ventral marginal lobe. The chondrophore is remarkably large and strong, concave, striated within, and projects much within the margin of the hinge-plate. The pallial sinus is large and deep. Ligament external, strongly developed (from Verrill & Bush).

Megayoldia is known in the Oligocene and probably occurs from Eocene to Recent. *Yoldia emersoni* Dall⁸² described from the Eocene of Alaska may belong to this subgenus. Makiyama⁸³ has discussed the relationships of several Japanese species belonging to *Megayoldia*.

Yoldia (Megayoldia) martyria Dall.

Yoldia martyria Dall, *Nat. Hist. Soc. Brit. Columbia, Bull.* No. 2, January, 1897, p. 9, pl. 2, fig. 15. "Puget Sound, 35-135 fms.; Gulf of California off the Island of San Pedro Martir, in 65 fms.; U. S. Fish Commission steamer Albatross." —Dall, Checklist Rec. Biv. Moll. (Southwest Museum), 1916, p. 11. Kasa-an Bay, Alaska, to Gulf of California. —Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 13. Kasa-an Bay, Alaska, to Gulf of California. —I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.* Vol. 1, 1924, p. 29, pl. 39, fig. 11. Type locality and range same as cited by Dall. —Keen, Check List West North Amer. Mar. Moll. (Stanford Univ. Calif.), 1937, p. 27. Range: Lat. 23°-55° N.

Type Locality: (According to I. S. Oldroyd), off San Pedro Martir Island, Gulf of California. Type in U. S. Nat. Mus.

Range: Kasa-an Bay, Alaska, to the Gulf of California.

Shell olive-greenish, smooth, nearly equilateral; posterior end roundly pointed, compressed and slightly recurved; hinge with 21 anterior and 17 posterior teeth.

Subgenus **Orthoyoldia** Verrill & Bush.

Orthoyoldia Verrill & Bush, *Amer. Jour. Sci.*, Ser. 4, Vol. 3, 1897, p. 55. "Type *Orthoyoldia scapina* (Dall)." —Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, 1898, p. 859. Type: *Orthoyoldia scapina* (Dall).

Type (by original designation): *Orthoyoldia scapina* (Dall). [= *Yoldia scapania* Dall, *Proc. U. S. Nat. Mus.*, Vol. 12, 1889, p. 254, pl. 13, fig.

⁸² *Yoldia emersoni* Dall, Harriman Alaska Exped., Vol. 4, 1910, p. 104, pl. 9, fig. 8. "Upper beds, 3373." Beds near the camp on the eastern side of Chichagof Cove. Upper beds of Stepovak Series. Eocene.

⁸³ Makiyama, J., *Mem. Coll. Sci. Kyoto Imper. Univ.*, Ser. B, Vol. 10, no. 2, 1934, pp. 130-132.

6. U. S. Fish Commission station 2762, "east of Rio Janeiro, in 59 fathoms, mud; bottom temperature 57°F."].

Shell oblong, gaping, blunt or rounded at both ends, without a distinct rostrum; no carina. Pallial sinus large and broad. Teeth numerous in both series (Verrill & Bush).

The shells of *Orthoyoldia* are soleniform or elongate-elliptic in shape.

Orthoyoldia is known from the Miocene⁶⁴ of the Caribbean region. It is now living in that region and is represented by at least one species in tropical west American waters.

***Yoldia (Orthoyoldia) panamensis* Dall.**

Yoldia (Orthoyoldia) panamensis Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 380. U. S. S. *Albatross* station 3354, "Gulf of Panama, in 322 fathoms, mud, bottom temperature 46°F." Also at station 3355, in 182 fathoms.

Yoldia panamensis Dall, *Zetek, Rev. Nueva*, Nos. 1 & 2, 1918, p. 38. Panama.

Type Locality: Gulf of Panama, in 322 fathoms, mud. Type No. 122,900 U. S. Nat. Mus.

Range: Gulf of Panama.

The shell of this species is small, narrow, elongate, and very inequilateral; resilium small, vertical, triangular and wholly internal; no visible external ligament; hinge with 18 anterior and 52|25|-27 posterior teeth.

Subgenus ***Yoldiella*** Verrill & Bush.

Yoldiella Verrill & Bush, *Amer. Jour. Sci.*, Ser. 4, Vol. 3, January, 1897, p. 55. "Type *Yoldiella lucida* (Loven)," figs. 3, 4, 11, 14. —Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, 1898, p. 861. Type: *Yoldiella lucida* (Loven).

Type (by original designation): *Yoldiella lucida* (Loven). [= *Yoldia lucida* Lovén, *K. Vet. Akad. Forh.*, 1846 (Index Moll. Lit. Scandinaviae occid. Habit.), p. 34. "Boh.-Finn." Illustrated as *Portlandia lucida* Loven, by Sars, *Bid. Kunds. Norg. Ark. Fauna. I. Moll. Reg. Arct. Norvegiae*, 1878, p. 37, Tab. 4, figs. 8a, 8b. West Coast of Norway in 20-650 fathoms. Also in Arctic and north Atlantic. —Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, 1898, p. 861, pl. 77, fig. 2; pl. 80, fig. 3 (as *Yoldiella lucida*)].

This group includes a large number of small, mostly deep-sea species, with glossy, iridescent, ovate, and usually wedge-shaped shells, nearly always having a slight postero-ventral sinuosity, which feebly defines an obscure, blunt, rostral region, without any definite carination. The shells do not gap, but close tightly, except that at the rostral angle of some species there may be a slight divergence. The internal cartilage, which is often relatively large, occupies a simple notch, which interrupts the hinge margin more or less completely and generally shows externally in a dorsal view; the notch usually terminates within on the inner or inferior surface of the hinge-plate, and is often bounded within by a slight ridge. A weak external ligament is present on the postero-dorsal margin. A relatively small, pallial sinus has been observed in several of the species, but is usually indistinct. The siphon tubes, as observed in a few of the species, are slender and united for more than half their length. (Verrill & Bush).

⁶⁴ See *Yoldia (Orthoyoldia) ovalis* Gubb, Woodring, *Carnegie Inst. Washington, Publ.* 366, 1925, p. 22, pl. 1, figs. 20, 21. Bowden, Jamaica: Miocene. *Yoldia bocasensis* Olsson (*Bull. Amer. Paleont.*, Vol. 9, *Bull. No.* 89, 1922, p. 348 (176), pl. 31 (28), figs. 21, 22. "Gatun Stage: Bocas del Toro") from the Miocene of Panama, is a similar species.

***Yoldia (Yoldiella) cecinella* Dall.**

Yoldia cecinella Dall, *Proc. U. S. Nat. Mus.*, Vol. 52, December 27, 1916, p. 399. "Station 2823, off La Paz, Gulf of California, in about 26 fathoms." —Dall, *U. S. Nat. Mus.*, *Bull.* 112, 1921, p. 14. Aleutian Islands to Gulf of California. —I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 34. Type locality and range same as cited by Dall. —Keen, *Check List West North Amer. Mar. Moll.* (Stanford University Press), 1937, p. 27. Lat. 23°-55° N.

Type Locality: Off La Paz, Lower California, Mexico, in about 26 fathoms. Type No. 211,424 U. S. Nat. Mus.

Range: Aleutian Islands to the Gulf of California.

Shell minute, polished, smooth, nearly equilateral, the margins arcuate above and below, the anterior end rounded, the posterior more pointed and slightly longer; beaks low and inconspicuous, with neither lunule nor escutcheon indicated; hinge with 6 or 7 minute teeth on each side of the subumbonal, very small resilifer. Length, 5 mm.; height, 2.6 mm.; diameter, 1.5 mm. (Dall).

***Yoldia (Yoldiella) chilénica* Dall.**

Yoldia (Yoldiella) chilénica Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 380. U. S. S. *Albatross* station 2781 "on the southern coast of Chile (Lat. 51° 52' S.), in 348 fathoms, mud, bottom temperature 50° F." Also at station 2782, in 258 fathoms.

Type Locality: Southern coast of Chile (Lat. 51° 52' S.), in 348 fathoms, mud. Type No. 96,923 U. S. Nat. Mus.

Range: Southern coast of Chile.

This species has not been illustrated but according to Dall it has somewhat the appearance of young *Yoldia thraciiformis*. Hinge with 19 anterior and 17 posterior teeth.

***Yoldia (Yoldiella) dicella* Dall.**

Yoldia (Yoldiella) dicella Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 382. U. S. S. *Albatross* station 3418, "off Acapulco, Mexico, in 660 fathoms, sand, bottom temperature 39° F."

Type Locality: Off Acapulco, Mexico, in 660 fathoms, sand. Type No. 122,917 U. S. Nat. Mus.

Range: Known only from the type locality.

This is said to be a "spade-shaped" little species quite distinct from others of the genus in west American waters. Hinge with about 10 anterior and 15 posterior teeth.

***Yoldia (Yoldiella) granula* Dall.**

Yoldia (Yoldiella) granula Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 382. U. S. S. *Albatross* station 2778, "in Magellan Straits, in 61 fathoms, bottom temperature 47° 9 F."

Type Locality: Magellan Straits, in 61 fathoms. Type No. 110,693 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell minute, oval, equilateral, moderately tumid, smooth, covered with a polished straw-colored periostracum; interior porcellanous, with a very slight pallial sinus and smooth margins; hinge line with about six teeth on

either side of a well-developed resilium, the most anterior tooth of all a little more distant and notably larger than any of the others. Length, 1.7; alt. 1.2; max. diam. 1.0 mm. (Dall).

***Yoldia (Yoldiella) indolens* Dall.**

Yoldie[a] (Yoldiella) indolens Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1898, p. 381. U. S. S. *Albatross* station 2784, "on the southern coast of Chile, in 194 fathoms, mud, bottom temperature 51°.9 F." Also at station 2785, in 122 fathoms.

Type Locality: Southern coast of Chile, in 194 fathoms, mud. Type No. 122,740 U. S. Nat. Mus.

Range: Southern coast of Chile.

Apparently no illustration has been given of this species. According to Dall it resembles *Yoldia chilénica* but is more inflated. Hinge with about a dozen teeth on each side of the pit for the resilium.

***Yoldia (Yoldiella?) infrequens* Dall.**

Yoldia (Yoldiella?) infrequens Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 381. U. S. S. *Albatross* station 2784, "in 194 fathoms, mud, off the coast of southern Chile, bottom temperature 51°.9 F." Also at station 2783, in 122 fathoms.

Type Locality: Off the coast of southern Chile, in 194 fathoms, mud. Type No. 110,692 U. S. Nat. Mus.

Range: Off the southern coast of Chile.

Shell very small, callistaeform, tumid; both ends of shell evenly rounded; concentrically striated; hinge with about 9 anterior and 13 posterior teeth. Length, 4.4 mm.; height, 3.5 mm.; maximum diameter, 2.0 mm.

***Yoldia (Yoldiella) leonilda* Dall.**

Yoldia (Yoldiella) leonilda Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 382. U. S. S. *Albatross* station, 3360, "Gulf of Panama, in 1672 fathoms, sand, bottom temperature 42° F."

Yoldia leonilda Dall, *Zetek, Rev. Nueva*, Nos. 1 & 2, 1918, p. 38. Panama.

Type Locality: Gulf of Panama, in 1,672 fathoms, sand. Type No. 122,909 U. S. Nat. Mus.

Range: Gulf of Panama.

Shell small, oval, smooth, white; hinge with 12 anterior and 14 posterior teeth.

***Yoldia (Yoldiella?) mantana* Dall.**

Yoldia (Yoldiella?) mantana Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 381. U. S. S. *Albatross* station 2792, "in 401 fathoms, mud, off Manta, Ecuador, bottom temperature 42°.9 F."

Type Locality: Off Manta, Ecuador, in 401 fathoms, mud. Type No. 122,756 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell small, elongate-oval, white, nearly equilateral, with a pale yellowish periostracum; surface mostly smooth but with a few irregular concentric striae; hinge with about 9 anterior and 10 or 11 posterior teeth. Length, 5.0 mm.; height, 3.2 mm.; maximum diameter, 2.5 mm.

Genus **Cyrilla** A. Adams.

Huxleyia A. Adams, *Ann. & Mag. Nat. Hist.*, Ser. 3, Vol. 5, April, 1860, p. 303. Sole species: *Huxleyia sulcata* A. Adams. See also p. 432.

Not *Huxleyia* Bowerbank. Dall (1898), cited the use of the name *Huxleyia* by Bowerbank but we have not noticed a citation to the original reference.

Not *Huxleya* Dyster, *Quart. Jour. Micr. Soc.*, Vol. 6, 1858, p. 260.

Cyrilla A. Adams, *Ann. & Mag. Nat. Hist.*, Ser. 3, Vol. 5, June, 1860, p. 478. "In a former paper I gave the name *Huxleyia* to a new genus of bivalve Mollusca. Should, however, this name have been already used, which is not improbable, *Cyrilla* might be substituted for it." —A. Adams, *Ann. & Mag. Nat. Hist.*, Ser. 3, Vol. 9, 1862, p. 295. —A. Adams, *Journ. de Conchyl.*, Vol. 16, 1868, p. 41. —Dall, *Trans. Wagner Free Inst. Sci.*, Vol. 3, Pt. 4, 1898, p. 601. Type: *H. sulcata* A. Adams.

Type (by monotypy): *Huxleyia sulcata* A. Adams. [*Ann. & Mag. Nat. Hist.*, Ser. 3, Vol. 5, 1860, p. 303. "Hab. 16 miles from Mino-Sima, Straits of Korea; dredged from 63 fathoms." —A. Adams, *Journ. de Conchyl.*, Vol. 16, 1868, p. 42, pl. 4, fig. 2. Original locality cited.]

Shell suborbicular, minute, exteriorly smooth or with simple sculpture; pallial line entire; fossette for ligament enlarged and rounded; anterior cardinal teeth reduced, posterior series of teeth well developed; interior of shell not nacreous.

Nucinella Wood⁸⁵ with the type *Nucula miliaris* Deshayes from the Eocene of the Paris Basin, is a related genus. The name *Pleurodon* Wood was replaced by *Nucinella* Wood due to the earlier use of *Pleurodon* by Harlan. *Pleurodon microdus* Boettger, *P. cinctus* von Koenen, *P. dobergensis* Lienenklaus and *P. zinndorfi* Zilch⁸⁶ all referred to *Pleurodon*, have been described from the Oligocene of Germany and the genus has been cited from Eocene to Recent. *Pleurodon gunteri* Mansfield⁸⁷ has been described from the Miocene, and *P. woodii* Dall⁸⁸ from the Miocene and Pliocene of Florida, and *P. adamsii* occurs in the waters off the coast of Florida. E. A. Smith⁸⁹ recorded a species living off the Cape of Good Hope, under the name of *Nuculina ovalis* Wood. It is probably a distinct species from the one originally described under that name from the Crag, Pliocene of England. Jeffreys⁹⁰ cited *Nucinella ovalis* Wood from the Strait of Korea in 40 fathoms but probably that record can be referred to some similar species inhabiting the North Pacific. Lamy described "*Nucinella Serrei*"⁹¹ from Brazil, and Cotton & Godfrey have recently added a new species, "*Pleurodon hedleyi*," to the fauna of South Australia. Species of *Cyrilla* are also known off the coasts of New Zealand⁹² and Japan as well as off North and Central America.

⁸⁵ *Nucinella* Wood, *Palaeontogr. Soc., Monogr. Crag. Moll.*, Pt. 2, 1850, p. 72. Species cited: *Nucula miliaris* Deshayes. In the synonymy of which was included *Pleurodon ovalis* S. Wood, 1840. *Nucinella* to replace *Pleurodon* Wood, 1840 [not *Pleurodon* Harlan, *Jour. Acad. Nat. Sci. Philadelphia*, Vol. 6, 1831, p. 284]. —Schenck, *Jour. Paleo.*, Vol. 13, no. 1, January, 1899, p. 39. "*Nucinella* Wood, 1850 (genotype, *N. miliaris* (Deshayes), from the Eocene of the Paris Basin)" [= *Nucula miliaris* Deshayes, *Descript. Coq. Foss. env. Paris*, Vol. 1, Livr. 15, 1829, p. 235, pl. 36, figs. 7, 8, 9].

⁸⁶ *Pleurodon zinndorfi* Zilch, *Arch. f. Molluskenkunde*, Bd. 69, No. 5-6, November, 1937, p. 250, figs. 1a, 1b. "In den mittelloligozänen Meeressanden des Mainzer Beckens, am Welschberg bei Waldböckelheim."

⁸⁷ *Pleurodon gunteri* Mansfield, *Florida State Geol. Surv., Bull.* No. 8, 1932, p. 38, pl. 2, figs. 4 and 6. Vaughan Creek, Walton County, Florida. Upper Middle Miocene.

⁸⁸ *Pleurodon woodii* Dall, *Trans. Wagner Free Inst. Sci.*, Vol. 3, pt. 4, 1898, p. 600, pl. 24, fig. 10. "Pliocene marls of the Caloosahatchie, Florida." —Mansfield, *Florida State Geol. Surv., Bull.* No. 8, 1932, p. 37, pl. 2, figs. 1 and 3. *Cancellaria* zone—borrow pit, Jackson Bluff, Leon County, Florida; upper Miocene.

⁸⁹ *Nuculina ovalis* (S. Wood), E. A. Smith, *Sci. Rept. Voy. Challenger, Zool.*, Vol. 13, 1885, p. 230, pl. 19, figs. 1, 1b. "Simon's Bay, Cape of Good Hope, in 15 to 20 fathoms."

⁹⁰ Jeffreys, J. G., *Jour. Linn. Soc. London*, Vol. 14, 1879, p. 420.

⁹¹ *Nucinella serrei* Lamy, *Bull., Mus. Nat. d'Hist. Nat. (Paris)*, Vol. 18, no. 7, 1912, p. 432, figs. 1, 2, 3. Brazil.

⁹² *Pleurodon maoianus* Hedley, *Rec. Australian Mus.*, Vol. 5, no. 2, January 28, 1904, p. 87, fig. 14. "from 5 fathoms off Anchor Island, Dusky Sound, New Zealand."

Two generic names *Cyrrillona* and *Cyrrillista* have been proposed by Iredale⁹³ for austral species formerly referred to *Cyrrilla* or *Nuculina*. *Diabolica* Jousseaume⁹⁴ is referable to *Cyrrilla* as indicated by Thiele.

Lamy⁹⁵ has reviewed many of the species referred to *Pleurodon* and *Nucinella*.

KEY TO THE SPECIES OF *Cyrrilla*.

- | | |
|---|-------------------|
| A. Lateral tooth short, ligamentary pit large | <i>munita</i> |
| B. Lateral tooth long, ligamentary pit small | <i>subdolosus</i> |

Cyrrilla munita Carpenter in Dall.

Cyrrilla munita Carpenter, Dall, *Trans. Wagner Free Inst. Sci.*, Vol. 3, pt. 4, April, 1898, p. 602. "From thirty fathoms off Catalina Island, California." —Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 14 (under the genus *Pleurodon*). Santa Barbara Islands to the Gulf of California. —Schenck, *Jour. Paleo.*, Vol. 13, no. 1, January, 1939, p. 39, pl. 6, figs. 14 and 15. Type localities of *Cyrrilla munita* and *Nucula petriola* cited.

Nucula petriola Dall, *Proc. U. S. Nat. Mus.*, Vol. 52, December 27, 1916, p. 395. "Off Santa Rosa Island, California, in 53 fathoms, mud." —I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 12. Type locality cited.

Nuculina munita Carpenter, Lamy, *Bull. Mus. Nat. d'Hist. Nat. (Paris)*, Vol. 18, no. 7, 1912, pp. 430, 431. Earlier records cited.

Pleurodon munitum (Carpenter) Dall, I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 36. Locality and range same as cited by Dall.

Nucinella munita [Carpenter in Dall], Keen, Check List West North Amer. Mar. Moll., (Stanford Univ., Calif.), 1937, p. 23, Lat. 23°-34° N.

Type Locality: Off Catalina Island, California, in 30 fathoms. Type of *Nucula petriola*, No. 271,416 U. S. Nat. Mus.

Range: Santa Rosa Island, California to ? Lat. 34° S.

A small rounded-quadrate shell with a large fossette.

Subgenus *Neopleurodon* Hertlein & Strong, nov.

Type: *Pleurodon subdolosus* Strong & Hertlein.

Shell minute, suborbicular; exteriorly smooth or with simple sculpture; pallial line entire; hinge plate well developed with teeth forming a gentle arc; a long lateral tooth present in right valve; interior not nacreous.

Neopleurodon differs from *Cyrrilla* in the more even arcuate series of teeth and in the very small area for the ligament, and longer lateral tooth.

Judging from the illustration, *Pleurodon ovalis* Wood⁹⁶ from the Pliocene of England may belong to this subgenus, as may "*Pleurodon hedleyi*" Cotton & Godfrey⁹⁷.

⁹³ Iredale, T., *Rec. Australian Mus.*, Vol. 17, no. 4, September 4, 1929, pp. 160, 188. *Cyrrillona*, "Type *Cyrrilla dalli* Hedley." *Mem. Australian Mus.*, Mem. 4, Vol. 1, pt. 5, July 29, 1902, p. 296, fig. 44. "off Port Kembla, in 63-75 fathoms, and off Cape Three Points in 41-50 fathoms." *Cyrrillista*, "Type *Nuculina concentrica* Verco." Illustrated by Cotton & Godfrey, *Moll. South Australia*, Pt. 1, 1938, p. 56, fig. 38.

⁹⁴ *Diabolica diabolica* Jousseaume, *Le Naturaliste*, Ann. 19, (Ann. 11, Ser. 2), no. 257, November 15, 1897, p. 265. Sole species: *Diabolica diabolica* Jousseaume. No locality cited. —Lamy, *Mem. Inst. Egypt*, Vol. 37, 1938, p. 8, fig. 1 (as *Nucinella (Cyrrilla) diabolica*). Gulf of Akaba.

⁹⁵ Lamy, E., Sur le Genre *Pleurodon* ou *Nucinella* S. Wood, avec description d'une espèce nouvelle. *Bull. Mus. Nat. d'Hist. Nat. (Paris)*, Vol. 18, no. 7, 1912, pp. 429-433. See also Lamy, E., *Journ. de Conchyl.*, Vol. 60, no. 2, December 15, 1912, pp. 108, 109 (footnote).

⁹⁶ *Pleurodon ovalis* Wood, *Mag. Nat. Hist.*, New Ser., Vol. 4, 1840, p. 230, Suppl. pl. 13, fig. 1. "Coralline crag Ramsholt and Sutton." —See illustration by Wood, *Palaeontogr. Soc., Monogr. Crag. Moll.*, Pt. 2, 1850, p. 72, pl. 10, figs. 4a, 4b, 4c.

⁹⁷ *Pleurodon hedleyi* Cotton & Godfrey, *Moll. South Australia*, Pt. 1. Handbook Flora and Fauna of South Australia, issued by South Australian Brit. Sci. Guild, Adelaide, 1938, p. 57, fig. 39. "100 fathoms, 40 miles south of Cape Wiles, South Australia."

***Cyrilla (Neopleurodon) subdolos* Strong & Hertlein.**

Pleurodon subdolos Strong & Hertlein, *Proc. Calif. Acad. Sci.*, Ser. 4, Vol. 22, no. 6, December 31, 1937, p. 162, pl. 35, figs. 14, 18, 19. "Lat. 23° 12' N., Long. 106° 29' W., dredged in 12 fathoms, about five miles west of Mazatlan, Sinaloa, Mexico."

Type Locality: Off Mazatlan, Mexico, in 12 fathoms. Type No. 6,970 Calif. Acad. Sci. Paleo. Type Coll.

Range: Known only from the type locality.

The more regularly oval shell, persistent dark epidermis, and different hinge are features separating *Cyrilla subdolos* from *C. munita* (Carpenter) Dall. *Cyrilla adamsi* Dall⁹⁵ from the Straits of Florida is a somewhat similar species but the hinge is different.

Genus ***Malletia*** Desmoulins.

Malletia Desmoulins, *Act. Soc. Linn. Bordeaux*, Vol. 5, February 15, 1832, p. 85. ———Stoliczka, *Mém. Geol. Surv. India. Palaeont. Indica. Cret. Fauna South. India*, Vol. 3, 1871, pp. XX, 321. "Type, *M. chilensis*, Desm." ———Verrill & Bush, *Amer. Jour. Sci.*, Ser. 4, Vol. 3, January, 1897, p. 56. "Type *Malletia chilensis* Desmoulins." ———Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, 1898, p. 873. Type: *Malletia chilensis* Desmoulins. ———Dall, *Trans. Wagner Free Inst. Sci.*, Vol. 3, pt. 4, 1898, p. 581. "Type *M. norrisii* (Shy.) = *M. chilensis* Desm." ———Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 383. Type: *M. chilensis* Desmoulins. ———Cossmann & Peyrot, *Act. Soc. Linn. Bordeaux*, Vol. 66 (Conch. Neog. Aquit., Vol. 2, Livr. 1), 1912, p. 121. Genotype: *M. chilensis* Desmoulins. ———Grant & Gale, *Mém. San Diego Soc. Nat. Hist.*, Vol. 1, 1931, p. 132. Type: *M. chilensis* Desmoulins. ———Prashad, Siboga Exped., Mon. 53c, Lamell., 1932, p. 25. Type: *Malletia chilensis* Desmoulins.

Solenella Sowerby, *Proc. Zool. Soc. London*, for 1832 (issued March 13, 1833), p. 197. Sole species: *Solenella norrisii*. Valparaiso, Chile, in soft mud, at from 14 to 45 fathoms.

Pseudomalletia Fischer, *Man. de Conchyl.*, 1886, p. 987. Species cited: *P. obtusa* Sars and *P. transversa* Ponzi.

Type (designated by Stoliczka): *Malletia chilensis* Desmoulins.

Shell oval, compressed, smooth or concentrically furrowed, epidermis olive; ligament external, elongated, prominent; hinge with an anterior and posterior series of fine sharp teeth; interior subnacreous; pallial sinus large and deep; anterior adductor scar giving off a long oblique pedal line (Tryon: *Struct. and Syst. Conch.*)

The shell of *Malletia* s.s. is oblong elliptical, blunt posteriorly and without a definite rostrum or carination. The carinated and rostrate species with strong concentric sculpture can in many cases be referred to *Neilo* H. & A. Adams. The absence of a lunule, escutcheon and distinct rostrum serve to separate *Malletia* from *Yoldia*. A characteristic feature of the hinge of *Malletia* is that the posterior series of teeth are often more than twice as numerous as the anterior series.

Malletia has been recorded from upper Cretaceous⁹⁶ to Recent. It is primarily a Magellanic genus which is said to have reached the northern

⁹⁵ *Pleurodon adamsi* Dall, *Trans. Wagner Free Inst. Sci.*, Vol. 3, pt. 4, April, 1898, p. 601, pl. 24, fig. 2. "Dredged seven miles east of Fowey Rocks, Straits of Florida."

⁹⁶ *Malletia gracilis* Wilckens, *Wiss. Ergeb. Schwed. Südpolar-Exped.*, 1901-1903, Bd. 3, Lief. 12, 1910, p. 25, Taf. 2, fig. 4. Scymour Island, Antarctica; Cretaceous. The shape of this species is similar to that of *M. chilensis* Desmoulins.

Malletia ornata Sowerby has been reported from Patagonia in beds referred to the upper Cretaceous, also in beds referred to the Eocene by von Ihering (*An. Mus. Nac. Buenos Aires*, Ser. 3, Vol. 7, 1907, pp. 4, 228). The species bears a resemblance to *M. australis* Quoy & Gaimard of New Zealand. Powell (Shellfish of New Zealand, 1937, p. 55), referred *M. australis* to *Neilo* which he considered to be of generic status.

hemisphere during the Oligocene or Miocene, but the genus appears to be present in the Eocene of California.

One of the largest species of *Malletia* is *M. gigantea*¹⁰⁰ which occurs at Kerguelen Island in the south Atlantic. The size is noteworthy, the type specimen is 62 mm. in length. The posterior end of *M. gigantea* is expanded in a manner somewhat resembling *Yoldia thraciæformis*. E. A. Smith mentioned that the animal of *Yoldia subaequilateralis*¹⁰¹ "resembles that of *Solenella gigantea* in all respects excepting that the edge of the foot is bluntly serrated or scalloped."

***Malletia (Malletia) chilensis* Desmoulins.**

Malletia chilensis Desmoulins, *Act. Soc. Linn. Bordeaux*, Vol. 5, January 15, 1832, p. 85, pl. 1, figs. 1-8. Valparaíso, Chile, in 14 to 45 fathoms (according to Dall). ———H. & A. Adams, *Gen. Rec. Moll.*, Vol. 2, 1858, p. 549, pl. 126, figs. 6, 6a. ———Chenu, *Man. de Conchyl.*, Vol. 2, 1862, p. 181, fig. 913. ———Kobelt, *Illustr. Conchylienbuch*, Bd. 2, Lief. 10-11, 1881, p. 372, pl. 109, fig. 3. Chile. ———Tryon, *Struct. and Syst. Conch.*, Vol. 3, 1884, p. 249, pl. 126, fig. 34 (on expl. to pl. 126 as *Yoldia (Malletia) chilensis*). Valparaíso, Chile. ———Fischer, *Man. de Conchyl.*, Fasc. 10, 1886, p. 987, pl. 17, fig. 22. ———Verrill & Bush, *Amer. Jour. Sci.*, Ser. 4, Vol. 3, 1897, p. 56, fig. 9 (on p. 60). ———Stempell, *Zool. Jahrb.*, Suppl. Bd. 4 (Fauna chilensis, Bd. 1), Heft 2, July 1, 1898, p. 343 (and following pages), pl. 22, figs. 2, 3, 4, 9, 12; pl. 23, figs. 13, 14, 15, 16, 17; pl. 24, fig. 32 (anatomy). ———Stempell, *Zool. Jahrbuch.*, Suppl. Bd. 5 (Fauna Chilensis, Bd. 2), 1902, p. 219. Harbor of Coquimbo; Talcahuano, in 10 fathoms; Calbuco, in 10 fathoms. ———Dall, *Proc. U. S. Nat. Mus.*, Vol. 37, 1909, p. 251. Coquimbo, south to Talcahuano Bay, Chile. ———Heath, *Mém. Mus. Roy. d'Hist. Nat. Belg.*, Ser. 2, Fasc. 10, 1937, p. 5, pl. 10, fig. 87 (Anatomy). Talcahuano [?Talcahuano], Chile

Solenella norrisi Sowerby, *Proc. Zool. Soc. London* for 1832 (issued March 13, 1833), p. 197. "*Hab.* ad Valparaíso." "Discovered by Mr. Cuming, in soft mud, at from fourteen to forty-five fathoms depth." ———Sowerby, *Gen. Shells*, Vol. 2, pl. 237 (four figs.), 1833. "Dredged by Mr. H. Cuming at Valparaíso." ———Reeve, *Conch. Syst.*, Vol. 1, 1841, p. 48, pl. 30, figs. 1-4. ———Hanley, *Cat. Rec. Biv. Shells*, p. 17, 1843, p. 337, 18567, Suppl. 10, figs. 8, 1843. ———d'Orbigny, *Voy. Amér. Mérid.*, Vol. 5, 1846, p. 543. Dredged in 10 fathoms in the Bay of Valparaíso, Chile. ———Woodward, *Man. Moll.*, 1851-1856, p. 270, pl. 17, fig. 22. Ed. 2, 1868, p. 429, pl. 17, fig. 22. Reprint of Ed. 4 (1880), 1910, p. 429, pl. 17, fig. 22. Valparaíso, Chile. ———Hupé, *Hist. de Chile, Zool.*, Vol. 8, 1854, p. 306. Various parts of the coast of Chile. ———Deshayes, *Traité Elem. Conchyl.*, Vol. 2, 1839-1857 [1858], p. 270, pl. 34, figs. 5, 6, 7. Valparaíso, Chile. ———Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 164, pl. 226 (*Nuculidae* pl. 1), figs. 1 and 2. Valparaíso, Chile

Solenella norrisii Sowerby var. *brevis* Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 164, pl. 226 (*Nuculidae*, pl. 1). Valparaíso, Chile.

Type Locality: Valparaíso, Chile, in 14 to 45 fathoms, mud.

Range: Coquimbo to Talcahuano Bay, Chile.

Shell subovate, somewhat compressed, with polished olivaceous epidermis; beaks anterior to the middle; unornamented except by lines of growth; hinge with teeth very fine and very numerous posteriorly but very few anteriorly.

¹⁰⁰ *Solenella gigantea* E. A. Smith, *Ann. & Mag. Nat. Hist.*, Ser. 4, Vol. 16, 1875, p. 72. "*Hab.* Royal Sound, Kerguelen's Island." ———E. A. Smith, *Phil. Trans. Roy. Soc. London*, Vol. 168, 1879, p. 187, pl. 9, fig. 19. Royal Sound, both at Observatory Bay and near the eastern shore of Swain's Harbour, on mud in about 10 fathoms.

Malletia gigantea E. A. Smith, E. A. Smith, *Sci. Res. Voy. Challenger, Zool.*, Vol. 13, Lamell., 1885, p. 244. Betsy Cove, Kerguelen Island, in shallow water; also at Balfour Bay, in 20 to 60 fathoms. ———Lamy, *Bull. Mus. Nat. d'Hist. Nat. (Paris)*, Vol. 12, 1906, p. 203. Kerguelen Islands. ———Lamy, *Bull. Mus. Nat. d'Hist. Nat. (Paris)*, Vol. 21, no. 2, 1915, p. 76. Several localities in Kerguelen Islands.

¹⁰¹ *Yoldia subaequilateralis* E. A. Smith, *Ann. & Mag. Nat. Hist.*, Ser. 4, Vol. 16, 1875, p. 73. "*Hab.* Swain's Bay, Kerguelen's Island." ———E. A. Smith, *Phil. Trans. Roy. Soc. London*, Vol. 168, 1879, p. 187, pl. 9, fig. 18. Swain's Bay. Dredged in 7-10 fathoms in very sheltered water

Subgenus **Neilo** H. & A. Adams.

Neilo A. Adams, *Proc. Zool. Soc. London*, 1852, p. 93. Sole species: *Neilo cumingii* A. Adams. "It is from the shores of New Zealand." —H. & A. Adams, *Gen. Rec. Moll.*, Vol. 2, 1858, p. 549. —Verrill & Bush, *Amer. Jour. Sci.*, Ser. 4, Vol. 3, 1897, p. 57. Type: *N. cumingii* Adams. —Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, 1898, p. 877. Type: *Neilo cumingii* Adams. —Dall, *Trans. Wagner Free Inst. Sci.*, Vol. 3, pt. 4, 1898, p. 581. Type: *N. australis* Quoy & Gaimard (+*N. cumingii* A. Adams). —Suter, *Man. New Zealand Moll.*, 1913, p. 837. Type: *N. cumingii* A. Adams = *australis* Quoy & Gaimard.

Type (by monotypy): *Neilo cumingii* A. Adams. [*Proc. Zool. Soc. London*, 1852, p. 93. "It is from the shores of New Zealand." —H. & A. Adams, *Gen. Rec. Moll.*, Vol. 2, 1858, p. 549, pl. 126, figs. 7, 7a, 7b. —Chenu, *Man. de Conchyl.*, Vol. 2, 1862, p. 181, fig. 914. —Suter, *Man. New Zealand Moll.*, 1913, p. 837, pl. 58, figs. 2, 2a (as *Malletia australis* Quoy & Gaimard). New Zealand].

The subgenus *Neilo* differs from *Malletia* in the ark-like form and in that the surface of the valves is usually ornamented by concentric sculpture.

Neilo has been recorded from late Cretaceous to Recent in Patagonia, from the Helvetian, Miocene, of France, and from upper Oligocene to Recent in New Zealand. The species described as *Nucula abrupta* by Conrad from the Miocene of Astoria, Oregon, was later referred to *Neilo*, but, there is some doubt as to the generic assignment of the species. One species assigned to *Neilo* has been described from deep water off tropical western North America.

Spineilo Finlay & Marwick¹⁰², with the type *Malletia elongata* Marshall from the Wangaloan (Danian) of New Zealand, was proposed as a subgenus of *Neilo*, the latter considered by them as of generic status.

Malletia (Neilo) goniura Dall.

Malletia goniura Dall, *Proc. U. S. Nat. Mus.*, Vol. 12, 1889, p. 251, pl. 10, fig. 10. U. S. Fish Commission station 2793, "off the coast of Ecuador in 741 fathoms, mud; bottom temperature 38°.4 F."

Malletia (Neilo) [typ. error for *Neilo*] *goniura* Dall, Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 386, pl. 18, fig. 6. U. S. S. *Albatross* station 3360. Gulf of Panama, in 1672 fathoms, sand, bottom temperature 42° F. Also original locality cited.

Type Locality: Off the coast of Ecuador, in 741 fathoms, mud.

Range: Gulf of Panama to off the coast of Ecuador, in deep water.

This is a thin fragile shell on which two ridges radiate from the beak to the truncate posterior margin. Hinge of type described as possessing 19 anterior and 25 posterior teeth. Another specimen described by Dall from the Gulf of Panama apparently had 14 anterior and over 30 posterior teeth.

Subgenus **Minormalletia** Dall.

Minormalletia Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 385. Sole species: *Malletia (Minormalletia) arciformis* Dall.

Type (by monotypy): *Malletia (Minormalletia) arciformis* Dall.

Shell small, blunt, plump, with amphidetic ligament, no resilium, the pallial sinus large, no radial depressions or sculpture (Dall).

Marwick¹⁰³ has recorded *Minormalletia* from the medial Tertiary of New Zealand.

¹⁰² *Spineilo* Finlay & Marwick, *Geol. Surv. New Zealand, Palaeo. Bull.* No. 15, May 20, 1937, p. 17. "Genotype: *Malletia elongata* Marshall, Wangaloan (Danian), New Zealand," p. 17, pl. 1, figs. 4 and 5. "Wangaloa (Type), common; Boulder Hill, common." Danian, upper Cretaceous.

¹⁰³ Marwick, J., *Geol. Surv. New Zealand, Palaeo. Bull.* No. 18, 1931, p. 55.

***Malletia (Minormalletia) arciformis* Dall.**

Malletia (Minormalletia) arciformis Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 385, pl. 15, figs. 5 and 6. U. S. S. *Albatross*, station 3417, "off Acapulco, Mexico, in 493 fathoms, mud, bottom temperature 40°.6 F."

Type Locality: Off Acapulco, Mexico, in 493 fathoms, mud.

Range: Known only from the type locality.

The pallial sinus is notable in that the greater part of its basal scar is identical with the pallial line itself, whereas in most of the Malletinae the sinus tends to slope obliquely upward (Dall).

Dall pointed out that the profile of this species, although more rounded below and behind, is somewhat similar to that of *Arca adamsii* (Shuttleworth (MS)) E. A. Smith, a Caribbean species.

***Malletia (Minormalletia) benthima* Dall.**

Malletia (Minormalletia) benthima Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 386, pl. 15, figs. 1 and 2. U. S. S. *Albatross*, station 3417, "off Acapulco, Mexico, in 493 fathoms, mud, bottom temperature 40°.6 F."

Type Locality: Off Acapulco, Mexico, in 493 fathoms, mud. Type No. 122,927 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell small, thin, very inequilateral; hinge with 12-13 anterior and 17-18 posterior teeth.

The subgeneric position of the following species of *Malletia* is uncertain.

***Malletia faba* Dall.**

Malletia faba Dall, *Nat. Hist. Soc. Brit. Columbia, Bull.* No. 2, January, 1897, p. 10, pl. 2, fig. 10. "Off Sea Lion Rock, coast of Washington, in 477 fms.; off Queen Charlotte Islands, British Columbia, in 876 fms.; off Tillamook in 786 fms.; off San Diego, Cal., in 822 fms., U. S. Fish Commission." —Dall, Checklist Rec. Bivalve Moll., (Southwest Museum), 1916, p. 13. Queen Charlotte Islands, Brit. Columbia, to Lower California. —Dall, *U. S. Nat. Mus., Bull.* 112, 1921, p. 14. Queen Charlotte Islands, British Columbia, to Lower California. —I. S. Oldroyd, *Stanford Univ. Publ. Univ. Ser. Geol. Sci.*, Vol. 1, 1924, p. 37, pl. 13, fig. 16. Range same as cited by Dall. —Keen, Check List West North Amer. Mar. Moll., (Stanford Univ. Press), 1937, p. 22. Range: Lat. 30°-54° N.

Type Locality: Off Sea Lion Rock, Washington, in 477 fathoms. Type No. 122,569 U. S. Nat. Mus.

Range: Queen Charlotte Islands, British Columbia, to Lower California.

Shell thin, ovate, inflated, smooth, slightly inequilateral; hinge with about 9 small posterior and about 32 anterior teeth.

***Malletia inequalis* Dall.**

Malletia inequalis Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 383. U. S. S. *Albatross*, station 2772, "off Cape Virgins, in 31 fathoms, sand, and 2778, Straits of Magellan, in 61 fathoms, mud, bottom temperature 47°.9 F."

Type Locality: Off Cape Virgins, in 31 fathoms, sand, and Straits of Magellan, in 61 fathoms, mud. [Type locality here designated as off Cape Virgins, in 31 fathoms, sand].

Range: Off Cape Virgins, and Straits of Magellan.

The truncation behind, the coalescent pallial sinus, and the compressed form separate it from the other species (Dall). Hinge with 3 anterior and 24 posterior teeth.

***Malletia magellanica* E. A. Smith.**

Malletia magellanica E. A. Smith, *Proc. Zool. Soc. London*, 1881, p. 39, pl. 5, figs. 3, 3a. "Hab. Station 3, Mayne Harbour, 9 fathoms, greenish mud; and Cockle Cove, 2-32 fathoms, mud." —Mabille & Rochebrune, *Miss. Sci. Cap. Horn*, *Moll.*, Vol. 6, *Zool.*, Pt. 2, 1889, p. H 114. Mayne Harbor; Cockle Cove (E. Smith).

Type Locality: Mayne Harbor and Cockle Cove, Chile.

Range: Straits of Magellan and Magellanic region.

***Malletia patagonica* Mabille & Rochebrune.**

Malletia patagonica Mabille & Rochebrune, *Miss. Sci. Cap. Horn*, Vol. 6, *Zool.*, pt. 2, 1889, p. H 114, pl. 8, fig. 1: "Hab. —Punta-Arenas."

Malletia hyadesi Mabille & Rochebrune, *Miss. Sci. Cap. Horn*, Vol. 6, *Zool.*, pt. 2, 1889, p. H 114. "Hab. —Punta-Arenas."

Malletia magellanica Mabille & Rochebrune, *Dall, Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 383 (at least in part). Punta Arenas. Also off Cape Virgins, in 31½ fathoms, and Magellan Straits, in 77 fathoms.

Not *Malletia magellanica* E. A. Smith.

Type Locality: Punta Arenas, Chile.

Range: Southern Chile in the Magellanic region.

***Malletia peruviana* Dall.**

Malletia peruviana Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 384, pl. 10, figs. 3 and 5. U. S. S. *Albatross* station 4654, "N. 68° W., twenty-four miles from Aguja Point, Peru, in 1036 fathoms, mud, bottom temperature 37°.3 F."

Type Locality: Twenty-four miles N. 68° W., from Aguja Point, Peru, fathoms, ooze. Type No. 122,906 U. S. Nat. Mus.

Range: Known only from the type locality.

This species is remarkable for its almost blackish color and extremely shallow pallial sinus, which does not extend in front of the posterior adductor scar; the anterior end is unusually short and almost pointed (Dall). Hinge with about 10 anterior and 33 posterior teeth.

***Malletia truncata* Dall.**

Malletia truncata Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 384, pl. 17, fig. 1. U. S. S. *Albatross* station 3374, "southwest of Malpelo Island, Gulf of Panama, in 1823 fathoms, ooze, bottom temperature 36°.4 F." Also at station 3361, in 1471 fathoms, and station 3381, in 1772 fathoms.

Type Locality: Southwest of Malpelo Island, Gulf of Panama, in 1,823 fathoms, ooze. Type No. 122,906 U. S. Nat. Mus.

Range: Known only from the type locality.

Remarkable for its light yellow color, its surface devoid of radial sculpture or indented margin, and its bluntly truncate posterior end. In the latter character and its subequal division of the hinge teeth it recalls *Neilo*, but is without the rostration of that form (Dall). Hinge with 20 anterior and about 27 posterior teeth.

Genus *Tindaria* Bellardi.

Tindaria Bellardi, Monogr. Nuculidi Terr. Terz. del. Piemonte e Liguria, 1875, p. 28. Sole species: *Tindaria arata* Bellardi. —Verrill & Bush, *Proc. U. S. Nat. Mus.*, Vol. 20, 1898, p. 880. Type: *Tindaria arata* Bellardi. —Dall, *Trans. Wagner Free Inst. Sci.*, Vol. 3, pt. 4, April, 1898, p. 581. Type: *T. arata* Bellardi. —Sacco, Moll. Terr. Terz. Piemonte e Liguria, Pt. 26, December, 1898, p. 64. "(Tipo *T. arata* Bell.)." —Cossmann & Peyrot, *Act. Soc. Linn. Bordeaux*, Vol. 66 (Conch. Neog. Aquit., Vol. 2, Livr. 1), 1912, p. 125. Genotype: *Tindaria arata* Bellardi. —Woodring, *Carnegie Inst. Washington, Publ.* 366, 1925, p. 23. Type: *Tindaria arata* Bellardi.

Type (by monotypy): *Tindaria arata* Bellardi. [Mon. Nuculid. Terr. Terz. Piemonte e Liguria, 1875, p. 28, fig. 27. —Sacco, Moll. Terr. Terz. Piemonte e Liguria, Pt. 26, December, 1898, p. 64, pl. 12, figs. 55, 56. Helvetian and Tortonian of Italy].

Shell small, veneriform, strongly inflated; beaks turned forward; sculptured by concentric rugae of varying development; ligament external, opisthodontic; hinge uninterrupted below umbo, posterior series of teeth strongly curved, the anterior series of teeth are heavier, shorter and straighter; pallial sinus moderately developed, narrowly triangular.

Tindaria is known from the Miocene of France and Italy and Miocene to Recent in the Caribbean region. It is not known to occur with certainty in the Tertiary of the western Americas but several species have been described from west American waters between Sitka, Alaska, and Cape Horn.

Subgenus *Tindariopsis* Verrill & Bush.

Tindariopsis Verrill & Bush, *Amer. Jour. Sci.*, Ser. 4, Vol. 3, 1897, p. 59. "Type *T. agathida* (Dall)."

Type (by original designation): *T. agathida* (Dall). [= *Malletia* (*Tindaria*) *agathida* Dall, *Proc. U. S. Nat. Mus.*, Vol. 12, 1889, p. 252, pl. 13, fig. 10. South from St. Kitts, in 687 fathoms, east from Tobago, in 880 fathoms].

This subgenus was proposed for species with ovate shells, with a short rostrum, defined by a radial ridge and a furrow.

Tindaria (*Tindariopsis*) *sulculata* Gould.

Nucula sulculata Couthouy, Gould, *U. S. Explor. Exped.*, Vol. 12, 1852, p. 424, Atlas, 1856, pl. 37, figs. 539a-e. Orange Harbor, Patagonia.

Leda sulculata Couthouy, Hanley, *Thes. Conch.*, Vol. 3, 1860, p. 129 footnote. —Mabille & Rochebrune, *Miss. Sci. Cap. Horn*, Vol. 6, Zool., Pt. 2, 1889, p. H 113. Cape Horn. Orange Bay. —Stempel, *Sitzungsber. Kön. Preuss. Akad. Wiss. Berlin*, Jahrg. 1897, pp. 17-28. —Stempel, *Zool. Jahrb.*, Bd. 4 (Fauna Chilensis, Bd. 1), Heft 2, July 1, 1898, p. 343 (and following pages), pl. 22, figs. 1, 5, 6, 7, 8, 10, 11; pl. 23, figs. 19, 21; pl. 24, figs. 23, 24, 25, 26, 28, 29, 30, 31; pl. 25, figs. 33, 34, 35, 36, 37, 38, 40, 41, 43 (anatomy).

Not *Lembulus sulculatus* Risso, *Hist. Nat. Europ. Merid.*, Vol. 4, 1826, p. 320.

Leda lugubris A. Adams, *Proc. Zool. Soc. London*, 1856, p. 49. "Hab. ? Mus. Cuming." —E. A. Smith, *Proc. Zool. Soc. London*, 1881, p. 39. Port Rosario in 2-30 fathoms; Wolsey anchorage, in 17 fathoms. —Mabille & Rochebrune, *Miss. Sci. Cap. Horn*, Vol. 6, Zool., Pt. 2, 1889, p. H 113. Port Rosario (E. Smith).

Leda orangica Mabille & Rochebrune, *Miss. Sci. Cap. Horn*, Vol. 6, Zool., Pt. 2, 1889, p. H 113, pl. 8, fig. 3. "Hab. Baie Orange."

Tindaria (*Tindariopsis*) *sulculata* Gould, Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 390. Straits of Magellan. Also earlier records.

Type Locality: Orange Harbor, Chile.

Range: Cape Horn and Straits of Magellan.

The subgeneric position of the following species of *Tindaria* is uncertain.

Tindaria atossa Dall.

Tindaria atossa Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 388, pl. 15, figs. 3 and 4. U. S. S. *Albatross*, station 3392, "Gulf of Panama, in 1270 fathoms, hard bottom, temperature 36°.4 F." Also at station 3393, Gulf of Panama, in 1020 fathoms.

Type Locality: Gulf of Panama, in 1,270 fathoms, hard bottom. Type No. 122,920 U. S. Nat. Mus.

Range: Gulf of Panama.

Shell small, olivaceous, moderately polished, finely concentrically striated all over, with the beaks slightly anterior, the posterior end bluntly pointed, the anterior rounded; ligament small, amphidetic; anterior teeth six, posterior ten, the dorsal slopes gently, the basal margin roundly arcuate; interior white, margin entire. Measurements of the type: Length, 6.5 mm.; height, 4.5 mm.; maximum diameter, 3.0 mm. (From Dall).

Tindaria atossa resembles *T. panamensis* but the whole surface is sculptured and the posterior end is less elongated and pointed.

Tindaria compressa Dall.

Tindaria compressa Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 387, pl. 15, figs. 7 and 8; pl. 17, figs. 15 and 16. U. S. S. *Albatross* station 3360, "in 1672 fathoms, sand, bottom temperature 42° F." Also at station 3414, "southwest of the isthmus of Tehuantepec, in 2232 fathoms, green mud, bottom temperature 38°.5 F."

Type Locality: Lat. 6° 17' 00" N., Long. 82° 5' 0" W., in 1,672 fathoms, sand. Type No. 122,921 U. S. Nat. Mus.

Range: Southwest of the Isthmus of Tehuantepec to the Gulf of Panama, in deep water.

Shell small, thin, cythereiform, inequilateral, concentrically striated; hinge with 10-12 anterior and 21-25 posterior teeth.

Tindaria amabilis Dall¹⁰⁴ of the Antilles is a somewhat similar species.

Tindaria panamensis Dall.

Tindaria panamensis Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 388, pl. 17, figs. 10 and 12. U. S. S. *Albatross*, station 3392, "Gulf of Panama, in 1270 fathoms, hard bottom, temperature 36°.4 F."

Type Locality: Gulf of Panama, in 1,270 fathoms, hard bottom. Type No. 122,922 U. S. Nat. Mus.

Range: Known only from the type locality.

Surface with fine concentric threads which become much finer on the posterior third of the shell; hinge with 7 anterior and about 13 posterior teeth. Dimensions of type; length, 5.5 mm.; height, 4.3 mm.; maximum diameter 2.8 mm.

The more greenish color and dull surface of this species are said to be characteristic in comparison to similar species.

¹⁰⁴ *Malletia* (*Tindaria*) *amabilis* Dall, *Bull. Mus. Comp. Zool.*, Vol. 18, June, 1889, p. 438, pl. 40, fig. 8. —Dall, *Proc. U. S. Nat. Mus.*, Vol. 12, 1889, p. 252. In 607 fathoms, off St. Kitts, and in 889 fathoms east of Tobago.

Tindaria sp.¹⁰⁵, cited by Woodring from the Miocene of Bowden, Jamaica, is said to possess a similar shell but it is shorter and the posterior end is more inflated.

***Tindaria mexicana* Dall.**

Tindaria mexicana Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 389, pl. 17, figs. 11 and 14. U. S. S. *Albatross*, station 3418, "off the Mexican coast in 660 fathoms, sand, bottom temperature 39° F."

Type Locality: Off the Mexican coast, in 660 fathoms, sand. Type No. 122,925 U. S. Nat. Mus.

Range: Known only from the type locality.

Very similar to *T. smirna*, but with more prominent beaks; shorter and blunter, in proportion to height, and decidedly less pointed and produced behind (Dall). Hinge with 11 anterior and about 21 posterior teeth.

***Tindaria salaria* Dall.**

Tindaria salaria Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 387. "Dredged in Mid-Pacific, off Salar y Gomez Island, at U. S. S. *Albatross*, station 4693, in 1142 fathoms, manganese nodules, bottom temperature 35°.4 F."

Type Locality: Off Sala y Gomez, West of Chile, in 1,142 fathoms, manganese nodules.

Range: Known only from the type locality.

The shell of this species, in its general exterior characteristics, is said to resemble that of *Nucula proxima* Say.

***Tindaria smirna* Dall.**

Tindaria smirna Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 389, pl. 17, figs. 6 and 7. U. S. S. *Albatross*, station 3360, "Gulf of Panama, in 1672 fathoms, sand, bottom temperature 42° F."

Type Locality: Gulf of Panama, in 1,672 fathoms, sand. Type No. 122,919 U. S. Nat. Mus.

Range: Known only from the type locality.

Shell small, polished, subtriangular, of a blackish olive tint; smooth over two thirds of the surface, but near the basal margin there are about 10 concentric grooves crossed by very fine radial striae; hinge with about 8 anterior and 12 posterior teeth. Length 5.5 mm.; height, 4.0 mm.; maximum diameter, 2.7 mm.

Close to *T. atossa*, but much more brilliantly polished, the shell shorter, more turgid, more nearly equilateral, and with the ligament distinctly and subequally amphidetic, while in *T. atossa* it appears, to the naked eye, to be entirely opisthodetic, though on opening the valves a small portion is seen to pass in front of the beaks (Dall).

***Tindaria thea* Dall.**

Tindaria thea Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 390. U. S. S. *Albatross*, station 4654, "N. 68° W., twenty-four miles from Aguja Point, Peru, in 1036 fathoms, mud, bottom temperature, 37°.3 F."

¹⁰⁵ *Tindaria* (*Tindaria*) sp., Woodring, *Carnegie Inst. Washington, Publ.* 866, May, 1925, p. 28, pl. 1, figs. 22, 23. Bowden, Jamaica; Miocene.

Type Locality: 24 miles northwest of Aguja Point, Peru, in 1,036 fathoms, mud. Type No. 110,577 U. S. Nat. Mus.

Range: Known only from the type locality.

Just about the color of dark, wet, tea-leaves after they have been steeped. Longer and more pointed, and more attenuated behind, than *T. smirna*, which has very similar sculpture but a more yellowish color. In looking from below, the series of hinge teeth seems uninterrupted, but the black color of the semi-internal resilium can be seen through the interstices, as it is situated above the tooth-line (Dall). Hinge with 8 anterior and 14 posterior teeth.

***Tindaria virens* Dall.**

Malletia (Tindaria) virens Dall, *Proc. U. S. Nat. Mus.*, Vol. 12, 1889, p. 254, pl. 13, fig. 3. "In 122 to 449 fathoms, mud, on the west coast of Patagonia; temperatures 47° to 50° F."

Tindaria virens Dall, *Bull. Mus. Comp. Zool.*, Vol. 43, no. 6, October, 1908, p. 389. Coast of Southern Chile and western Patagonia, in 122 to 449 fathoms.

Type Locality: West coast of Chile, in 122 to 449 fathoms, mud.

Range: Coast of southern Chile, in 122 to 449 fathoms.

Lighter colored, with alternating zones and with sharper and deeper concentric sulci, than those exhibited by *T. atossa* of the Panama fauna, which is the most nearly related species (Dall, 1908).

EXPLANATION OF THE PLATES.

PLATE I.

- Fig. 1. *Nucula (Nucula) declivis* Hinds. Length 5 mm., height 4 mm., thickness (both valves) 2.9 mm. Hypotype, left valve, from Station 203-D-1, dredged in 15 fathoms (27 meters), in Lat. 10° 56' 05" N., Long. 85° 49' 25" W., Port Parker, Costa Rica. P. 380.
- Fig. 2. *Nucula (Nucula) declivis* Hinds. Length 4.8 mm., height 3.8 mm., thickness 1.6 mm. Hypotype, right valve, from Station 145-D-1, dredged in 13 fathoms (24 meters) in Lat. 26° 52' N., Long. 111° 53' W., Santa Inez Bay, east coast of Lower California. View of the interior. P. 380.
- Fig. 3. *Nucula (Nucula) declivis* Hinds. Length 4.6 mm., width 3.4 mm., thickness (both valves) 2.7 mm. Hypotype, left valve, from the same locality as the specimen shown in Fig. 2. P. 380.
- Fig. 4. *Nucula (Nucula) exigua* Sowerby. Length 5.7 mm., height 5.4 mm., thickness (both valves) 3.9 mm. Hypotype, left valve, dredged at Loc. 27595 (C.A.S.), San Bartolome (Turtle Bay), Lower California. P. 381.
- Fig. 5. *Nucula (Nucula) exigua* Sowerby. View of posterior end of specimen shown in Fig. 4.
- Fig. 6. *Nucula (Nucula) declivis* Hinds. View of posterior end of specimen shown in Fig. 1.
- Fig. 7. *Nucula (Nucula) declivis* Hinds. View of specimen shown in Fig. 1 but with less magnification.
- Fig. 8. *Nucula (Nuculopsis) schencki* Hertlein & Strong, sp. nov. Length 2.0 mm., height 1.7 mm., thickness (both valves), 1.0 mm. Holotype, left valve, from Station 195-D-9, dredged in 7 fathoms (12.6 meters), Lat. 15° 44' 28" N., Long. 96° 07' 51" W., Port Guatulco, Mexico. P. 384.
- Fig. 9. *Nucula (Nuculopsis) schencki* Hertlein & Strong, sp. nov. Length 2.8 mm., height 2.5 mm. Paratype, right valve, from the same locality as the holotype shown in Fig. 8. View of the interior. P. 384.
- Fig. 10. *Nucula (Nuculopsis) schencki* Hertlein & Strong, sp. nov. Dorsal view of the holotype shown in Fig. 8.

- Fig. 11. *Nuculana (Saccella) acuta* Conrad. Length 8.6 mm., height 4.8 mm., thickness (both valves) 3.4 mm. Hypotype, left valve, dredged at a depth of two fathoms at Cedar Keys, Florida, H. Hemphill collector (Loc. 5710). P. 392.
- Fig. 12. *Nuculana (Saccella) elenensis* Sowerby. Length 13.6 mm., height 7.0 mm., thickness (both valves) 5 mm. Hypotype, left valve, from Station 196-D-17, dredged in 23 fathoms (42 meters) in Lat. 15° 45' N., Long. 96° 05' 34" W., Tangola-Tangola Bay, Mexico. P. 393.
- Fig. 13. *Nuculana (Saccella) callimene* Dall. Length 14.5 mm., height 8.9 mm., thickness (both valves) 6.5 mm. Hypotype, left valve, from 3 miles south of Blanco Island, Gulf of Nicoya, Costa Rica. P. 393.
- Fig. 14. *Nuculana (Saccella) elenensis* Sowerby. Length 16 mm., height 8.5 mm., thickness (both valves) 6.5 mm. Hypotype, left valve, from the same locality as the specimen shown in Fig. 2. P. 393.
- Fig. 15. *Nuculana (Saccella) elenensis* Sowerby. Dorsal view of specimen shown in Fig. 14.
- Fig. 16. *Nuculana (Saccella) elenensis* Sowerby. Length 13.3 mm., height 6.8 mm., thickness (both valves) 4.8 mm. Hypotype, left valve, from the same locality as the specimen shown in Fig. 12. P. 393.
- Fig. 17. *Nuculana (Saccella) elenensis* Sowerby. Reproduction of figure of *Leda elenensis* Sowerby given by Hanley, Thes. Conch., Vol. 3, 1860, pl. 228 (*Nuculidae*, pl. 3), fig. 70. Panama.
- Fig. 18. *Nuculana (Saccella) elenensis* Sowerby. Reproduction of figure of *Leda elenensis* Sowerby given by Hanley, Thes. Conch., Vol. 3, 1860, pl. 228 (*Nuculidae*, pl. 3), fig. 71. Panama.
- Fig. 19. *Nuculana (Saccella) elenensis* Sowerby. Reproduction of figure of *Leda elenensis* Sowerby given by Hanley, Thes. Conch., Vol. 3, 1860, pl. 228 (*Nuculidae*, pl. 3), fig. 72. Panama.
- Fig. 20. *Nuculana cuneata* Sowerby. Reproduction of figure of *Leda cuneata* Sowerby given by Hanley, Thes. Conch., Vol. 3, 1860, pl. 228 (*Nuculidae*, pl. 3), fig. 93. "Valparaiso." [Not the record "New Guinea!"]. Dorsal view. P. 403.
- Fig. 21. *Nuculana cuneata* Sowerby. Reproduction of figure of *Leda cuneata* Sowerby given by Hanley, Thes. Conch., Vol. 3, 1860, pl. 228 (*Nuculidae*, pl. 3), fig. 92. Right valve. Same locality as cited for Fig. 20.
- Fig. 22. *Nuculana (Saccella) elenensis* Sowerby. Length 15.5 mm., height 8.1 mm. Hypotype, left valve, from the same locality as the specimen shown in Figs. 12 and 16. View of the interior. P. 393.

Figs. 12, 14-19, 22, illustrate the variability of *Nuculana elenensis*. Fig. 14. is a typical *N. ucupileensis* Pilsbry & Lowe but in view of the variability of the species we have considered these all to be referable to *N. elenensis*.

All the specimens illustrated on the plate except those shown in figures 17, 18, 19, 20, 21, are in the type collection of the Department of Paleontology of the California Academy of Sciences.

PLATE II.

- Fig. 1. *Nuculana (Saccella) eburnea* Sowerby. Length 12.4 mm., height 6.5 mm. Hypotype, right valve, from Station 199-D-1, dredged in 16 fathoms (29 meters) in Lat. 13° 18' N., Long. 87° 43' W., Meanguera Island, Gulf of Fonseca, El Salvador. P. 395.
- Fig. 2. *Nuculana (Saccella) eburnea* Sowerby. Length 11.2 mm., height 6 mm., thickness (both valves) 4.4 mm. Hypotype, left valve, from the same locality as the specimen shown in Fig. 1. P. 395.
- Fig. 3. *Nuculana (Saccella) eburnea* Sowerby. Length 13.3 mm., height 6.6 mm. Hypotype, left valve, from the same locality as the specimens shown in Figs. 1 and 2. View of the interior. P. 395.
- Fig. 4. *Nuculana (Saccella) laeviradius* Pilsbry & Lowe. Length 7.8 mm., height 4.4 mm., thickness (both valves) 3.6 mm. Hypotype, right valve, from

Station 145-D-1, -3, dredged in 4-13 fathoms (7.5-2.4 meters) in Lat. 26° 52' N., Long., 111° 53' W., Santa Inez Bay, east coast of Lower California. P. 396.

This illustration shows a comparatively smooth specimen in contrast to the one with strong concentric sculpture shown in Fig. 7.

Fig. 5. *Nuculana (Saccella) gibbosa* Sowerby. Length 36.8 mm., height 18.9 mm., thickness (one valve) 8.2 mm. Hypotype, left valve, from Station 213-D-11-17, dredged in 35 fathoms (63.7 meters) in Lat. 9° 44' 52"—9° 42' N., Long. 84° 51' 25"—84° 56' W., off Ballenas Bay, Gulf of Nicoya, Costa Rica. P. 395.

Fig. 6. *Nuculana (Saccella) impar* Pilsbry & Lowe. Length, 14.6 mm., height, 7.6 mm., thickness (both valves), 6.3 mm. Hypotype, right valve, from Loc. 23802 (C.A.S.), San Luis Gonzaga Bay, east coast of Lower California. P. 396.

The character of the ribbing, closely spaced near the beaks, widely spaced on the middle of the shell, then closely spaced near the base, is characteristic of this species.

Fig. 7. *Nuculana (Saccella) laeviradius* Pilsbry & Lowe. Length 6.0 mm., height 3.3 mm. Hypotype, right valve, from Loc. 23,802 (C.A.S.), San Luis Gonzaga Bay, east coast of Lower California. P. 396.

Fig. 8. *Nuculana (Saccella) gibbosa* Sowerby. Length 37.5 mm., height 19.8 mm., thickness (single valve) 7.9 mm. Hypotype, right valve, from the same locality as the specimen shown in Fig. 5. View of the interior. P. 395.

Fig. 9. *Nuculana (Politoleda) polita* Sowerby. Length 29.4 mm., height 14.0 mm., thickness (both valves, approximately) 9.6 mm. Hypotype, left valve, from Station 197-D-1, dredged in 14 fathoms (25 meters) in Lat. 14° 16' N., Long. 92° 03' W., 7 miles west of Champerico, Guatemala. P. 397.

Fig. 10. *Nuculana (Costelloleda) costellata* Sowerby. Length 22 mm., height 8.0 mm., thickness (both valves) 4.4 mm. Hypotype, left valve, from Station 143-D-1, dredged in 29 fathoms (53 meters) in Lat. 26° 58' 30" N., Long. 111° 57' 30", Santa Inez Bay, east coast of California. P. 398.

Fig. 11. *Adrana exoptata* Pilsbry & Lowe. Length 20.0 mm., height 6.0 mm., thickness (both valves, approximately) 3.0 mm. Hypotype, left valve, from Station 195-D-21, dredged in 18 fathoms (33 meters) in Lat. 15° 44' 45" N., Long. 96° 06' 55" W., Santa Cruz Bay, Mexico. P. 409.

Fig. 12. *Nuculana (Costelloleda) marella* Hertlein, Hanna & Strong, sp. nov. Length 32 mm., height 11.3 mm., thickness (both valves), 5.0 mm. Holotype, right valve, apparently from the Gulf of California. P. 399.

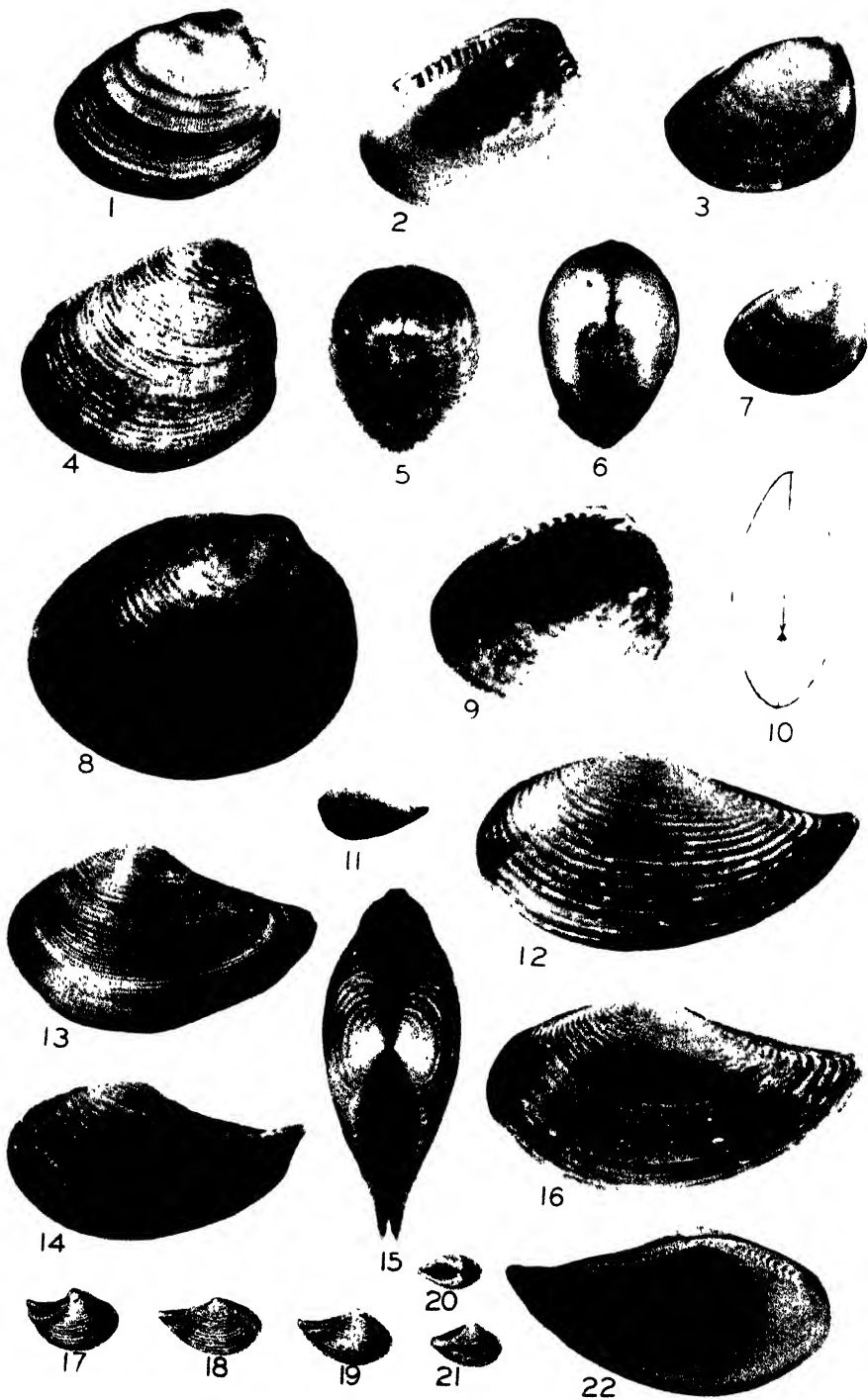
Fig. 13. *Nuculana (Costelloleda) marella* Hertlein, Hanna & Strong, sp. nov. View of interior of left valve of holotype.

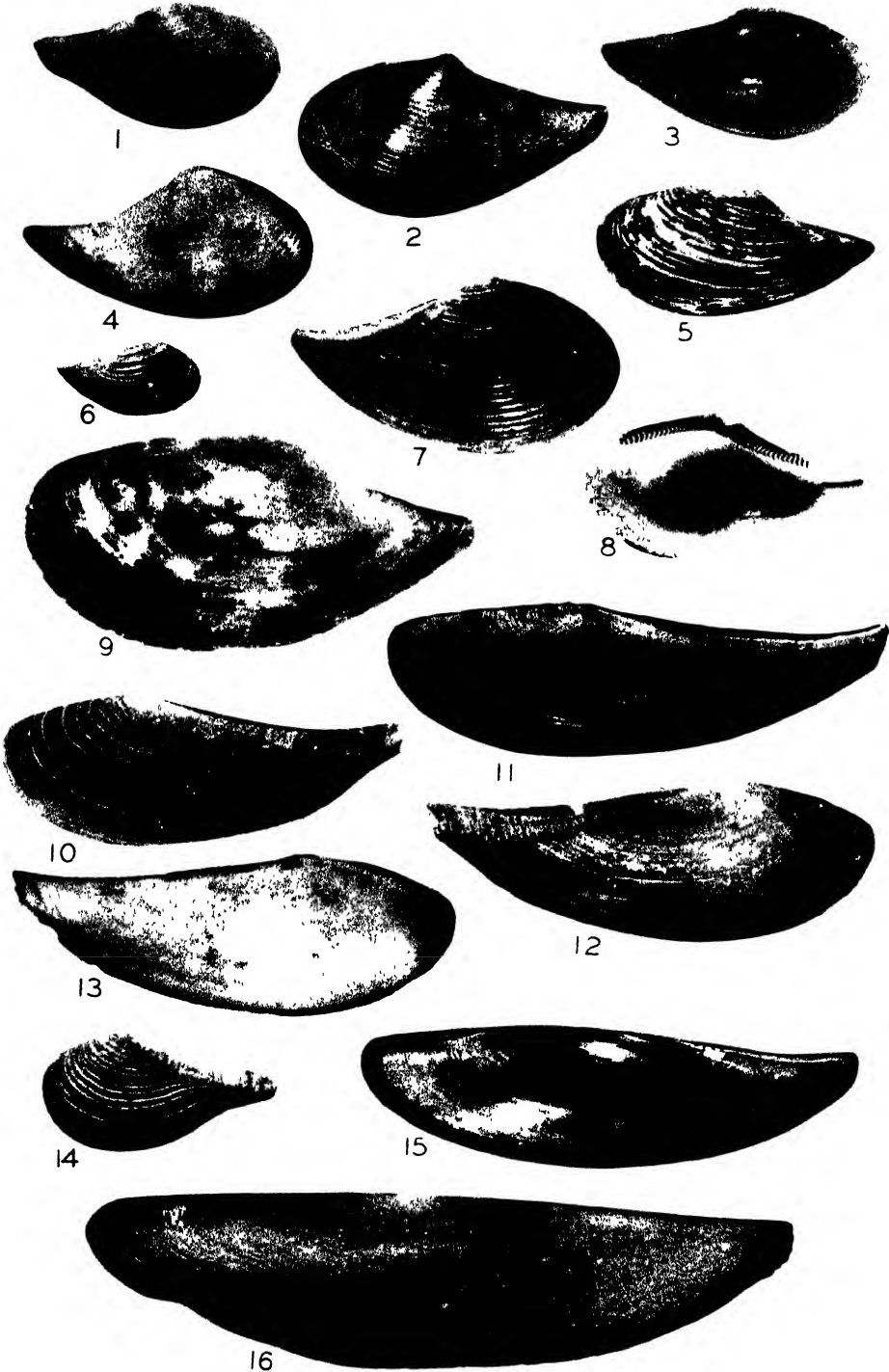
Fig. 14. *Nuculana (Thestylela) hamata* Carpenter. Length, 12.0 mm., height, 7.2 mm. Hypotype, left valve, from Station 126-D-12, dredged in 45 fathoms (82 meters) in Lat. 28° 20' N., Long. 115° 10' 30" W., east of Cedros Island, Lower California, Mexico. P. 400.

Fig. 15. *Adrana tonosiana* Pilsbry & Olsson. Length 33.1 mm., height 9.3 mm., thickness (both valves), 5.4 mm. Hypotype, left valve, from the same locality as the specimen shown in Fig. 9. P. 412.

Fig. 16. *Adrana elongata* Sowerby. Length 49.8 mm., height 12.0 mm., thickness (both valves) 5.5 mm. Hypotype, left valve, from Station 197-D-2, dredged in 14 fathoms (25 meters) in Lat. 14° 13' N., Long. 92° 02' W., 7 miles west of Champerico, Guatemala. P. 409.

All the specimens illustrated on this plate are in the type collection of the Department of Paleontology of the California Academy of Sciences.





26.

On the Electric Powers and Sex Ratios of Foetal *Narcine brasiliensis* (Olfers).

C. M. BREDER, JR.

New York Aquarium

&

STEWART SPRINGER

Bass Biological Laboratories

Although the small electric rays of the West Indies and Florida, *Narcine brasiliensis* (Olfers), are reasonably well known and recorded as giving electric shocks of some force, little seems to be known about their uterine embryos. Bean & Weed (1911) describe and figure the young of a 17-inch specimen which contained 14 fetuses and quote the reports of trammel-net fishermen along the Florida Keys regarding the electric powers of adults.

Trammel-net fishermen operate near the New York Aquarium's field station on Palmetto Key, which is in the vicinity of Boca Grande; see Breder (1939). They report that this ray is frequently taken in their gear. The shocking powers of these fish are sufficient to cause the operators to leave them in the trammel pockets when they clear their nets. Here they are left to die, being removed later when the fishermen reach home and spread their nets for drying.

One of these groups, the Spearing family, has been very kind in bringing interesting specimens to the laboratory. On July 8, 1940, they brought in a female *Narcine* of 295 mm. over all. It had aborted two premature young in their bucket and subsequently died. Manipulation caused it to extrude six more embryos. These were still in a living state and made the usual feeble efforts of ray embryos to swim. Nothing exceptional was noted in the manipulation incident to the extrusion, but when the young were handled four of them were noted to be capable of giving electric shocks. Although in a much weakened stage and not nearly ready to be born, this shock was sufficient to cause the senior writer to drop them, although this result was perhaps as much from surprise as from the current. The fine tingling sensation was typical of an interrupted or alternating current. The young were not all in a single stage of development. The range of their condition may be estimated by the following figures of length of embryo and diameter of yolks. The two largest, dead when received, and the two smallest, showed no reaction. Whether the two smallest had not yet developed the ability or whether they were so weakened as to be unable to discharge is not clear. The over-all lengths of the embryos were: male, 65, 67; female, 65, 73, 76, 78, 78 and 80 mm. The diameters of the yolks, respectively, were: 16, 14, 5, 6, 7, 8, 9 and 7 mm. The smallest female was abnormal in that the yolk sac appeared deflated and the ventral fins were slightly asymmetrical.

One of us, Springer, handling similar material, detected no electric effects from the young, but in this case the operator is particularly insensitive to electric shocks, while on the contrary the other one of us is more than usually sensitive to such effects. In addition, moreover, Mr. L. A. Krumholz, working at the same place with the latter, also felt the discharge.

The prenatal development of this ability to give off electric shocks suggests interesting complications in the internal circuits of the mother and young and causes one to wonder what the characteristics of the exterior total current might be like. Also the question of why no discharge was felt while the young were being forced out is of note. Suppression of or impossibility of discharge before birth, insulating or dissipating qualities in the parent, suggest themselves as possibilities.

The following data were taken from material obtained from a trammel-net at Punta Gorda Beach, July 7, 1939, giving total length and width in mm.

Males		Females			
		Gravid		Non-gravid	
T. L.	W.	T. L.	W.	T. L.	W.
300	160	310	173	375	308
295	164	284	165	271	152
228	124				
272	153				

The one gravid female of 310 mm. in length contained four males 82×50 , 79×42 , 81×43 , 81×43 , and one female 84×45 . The other of 284 mm. contained one male and three females of 78 to 80 mm. in length.

SEX RATIO OF EMBRYOS.

Length of Mother	Male	Female	% Male
284	1	3	25
295	2	6	25
310	4	1	80
432	9	5	64
	<hr/> 16	<hr/> 15	<hr/> 52

It is apparent that while there seems to be a tendency for the young to be predominantly of one sex in a given female, the young from so few as four females taken at widely separated times and places, when combined, closely approximate a 1-to-1 ratio. It would also appear that small mothers tend to produce more females while the large tend to a preponderance of male offspring, although of course, these specimens are too few for a basis of generalization.

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27.

A Study of the Activities of a Pair of *Galago senegalensis moholi*
in Captivity, Including the Birth and Postnatal
Development of Twins.

FLORENCE DE L. LOWTHER

Barnard College, Columbia University

(Plates I-VI).

CONTENTS.

	Page		Page
Introduction	433	Behavior of the adults.....	446
Description of <i>Galago senegalensis moholi</i> ..	434	Feeding	446
History and Classification—Paleontology....	434	Grooming	447
Distribution	437	Calls	448
Conditions of Observation.....	437	Sex Behavior	448
Functioning of the Structures Characteristic		Nesting Habits	449
of the Galago.....	438	Breeding Season and Period of Oestrus ...	449
The Head	438	Galago activities	449
a. Facial Expression. b. Lips. c. Nose .	438	Comparison with Breeding Habits of	
d. Eyes	440	Other Lemuroidea	450
e. Ears	440	Discussion of Environmental Causes of	
f. Jaws, Teeth and Tongue.....	441	Oestrus Change	451
The Limbs	442	Period of Gestation.....	452
a. The Hand and its Action.....	442	Birth and Number of Young.....	452
b. The Foot and its Action.....	443	Post-natal Condition of the Young	453
c. Volar and Solar Pads.....	443	Nursing and Care of the Young.	455
d. The Hind Limb and its Action.		Parental Attitudes	455
aa. Climbing. bb. Moistening of		Development of the Young Galago.....	456
Pads. cc. Jumping.....	443	Sleep	457
The Reproductive Organs.....	445	Acknowledgments	457
Disposition	446	Bibliography	458

INTRODUCTION.

Galagos, small, elusive lemuroids of arboreal and nocturnal habits, are found exclusively in Africa, where they are well known and widely distributed. Though the anatomical features of the many varieties of these animals have been studied, little seems to have been reported concerning the ways in which their structures function, nor is there any sufficient record of galago habits and family life. The account is spotty and incomplete, partially at least, because their nocturnal and tree-dwelling habits render observation difficult in the field and in captivity. In a study of the galago in captivity, an effort must be made to reproduce in some measure certain elements of its native environment, such as perching structures, space for jumping and dark places for retirement during daylight hours. The nocturnal habits of the group necessitate the observer's continuous occupancy of the animals' night quarters.

For more than three years, beginning September, 1937, I have made a close study of a pair of *Galago senegalensis moholi* A. Smith, a subspecies

of galago found in abundance throughout the savanna country of central and southern Africa. The opportunity to study these unique and interesting forms was enlarged by the fortunate birth of twins in captivity, making a family of four. Thus it has been possible to add, to the story of the behavior and disposition of the adults, a record of the birth and development of a male and female in captivity. While in the following discussion I have emphasized observations of their habits and family life, I have also described the functioning of those structures which are characteristic of the galago.

DESCRIPTION OF *Galago senegalensis moholi*.

The *Galago s. moholi* is a small, round-headed animal with a shortened face; large, almost naked, membranous ears with transverse ridges; round, wide-open eyes with vertical pupils, and a short rhinarium situated high on the face (Pl. I, Fig. 1).

The body length including the head of the adult male is $6\frac{1}{2}$ inches and the long, non-prehensile tail, which is used for balancing, $8\frac{1}{2}$ inches. The front limbs are shorter than the long hind limbs. The foot, which is highly specialized for jumping, has elongated calcaneum and navicular bones, providing adequate leverage for spectacular jumps.

The opposable huge hallux and less well developed pollex are primate characteristics possessed by the galago, as are the small, and in this species flattened, nails found on all the digits with the exception of the index toe. Here a claw, characteristic of the Lemuroidea, is found.

The dental formula of the *Galago s. moholi*, like that of the true lemurs, is

$$\begin{array}{ccccccc} 2 & i & 1 & c & 3 & p & 3 & m & & \\ \hline 2 & & 1 & & 3 & & 3 & & = & 36 \text{ total} \end{array}$$

The two pairs of procumbent lower incisors are flanked by modified canines, making the typical lemuroidean "tooth-comb."

The neck of the galago is short. The pelage is soft, heavy and almost chinchilla-like. The color of this subspecies is a mottled slate gray and silver with a light brown wash on the dorsal surface of the posterior half of the body. The ventral surface is largely white with slate gray on the deeper portions of the fur, seen only when the fur is separated.

On the inner surface of both arms and legs and across the chest, the pelage is clear yellow. There are white markings on the nose, around the neck and lower jaw. Through the usual gray of the dorsal pelage, longer black hairs protrude sparsely (Pl. IV, Fig. 9). There are black markings around the eye and along either side of the nose from the eye toward the upper lip (Pl. I, Fig. 1). The pelage is shorter near the hands and feet, and more silvery in color.

There are no well defined sex differentiations. The adult male is slightly larger than the female and the yellow of the pelage perhaps more marked. The length of the tails in this group varies between $8\frac{1}{2}$ and 10 inches. (The tail of the adult female under discussion is unnaturally short because of an injury to the tip sustained at capture (Pl. V, Fig. 12).

HISTORY AND CLASSIFICATION—PALEONTOLOGY.

In 1796 Étienne Geoffroy-St. Hilaire first described one of the "quadrumana" which the natives called "Galago," found in western Africa in the region of Senegal. A skull of this form was brought to him at the Museum in Paris by Michael Adanson who had spent some years in exploration of

the Senegal, and a skin was later provided by the Duc de Nivernais. The addition of pictures and descriptions furnished by Adanson led Geoffroy to the conclusion that this was a new type of animal which resembled in many respects the makis (lemurs), the lorises, and tarsier. It differed from each of these, however, to such an extent that he felt justified in calling this a new species intermediate, perhaps, between the *Loris* and the *Tarsius*. He determined to adopt for it the native name "Galago" to which he attached "du senegal," perhaps to distinguish it from two other forms (one larger and one smaller) which Adanson had reported to be present in that region. He described¹ it as possessing hind legs longer than the body, built for jumping; the front legs short; the tail longer than the body; ears large and membranous with transverse ridges.

Like the lemurs there were nails on hands and feet with the exception of the second toe which had a claw. The hind foot was very long due to the elongation of the calcaneum and scaphoid (navicular). The fur was grayish-tan on the dorsal surface and white with yellow on the under surface. It was also shorter on the hands and head while the under side of the hands and feet and the ears and nose were naked. The animal was described as arboreal and insectivorous. Geoffroy incorrectly stated that there were but one pair of upper incisors.

In 1836 Sir Andrew Smith described a galago of similar size which he found near the Limpopo River, Bechuanaland, South Africa, which closely resembled Geoffroy's *senegalensis*, but differed from it in two features.

1. On the ventral surface of the body the fur was white on the tips of the hair only; near the body it was slate gray.
2. There were two pair of incisors on the upper jaw instead of one pair as described for *senegalensis*.

On the basis of these differences he felt compelled to consider this a new species and called it *Galago moholi*, which is the Bechuana name for the animal in that locality.

"Had the upper jaw on this species not been furnished with four cutting teeth I should have been disposed to have considered it as identical with *Galago senegalensis* of Geoffroy." (Page 42).

For some years thereafter, the few species of galagos known were classified in accordance with the number of upper incisor teeth described for each. When, however, in 1851 Isadore Geoffroy-St. Hilaire reported that all galagos normally possessed two pair of upper incisors, the main reason for separating *Galago senegalensis* from *Galago moholi* disappeared.

"Les Galagoides de M. Smith sont les espèces qui n'auraient que deux incisives supérieures, et par conséquent trente-quatre dents en tout. Tels seraient, suivant lui les *Galago senegalensis* et *demidoffii*. Cette caractéristique est erronée; ces espèces ont normalement quatre incisives supérieures comme les autres; seulement deux sont caduques, comme il arrive si souvent chez les Lémurides." (Page 80.)

The *Galago moholi* is now recognized as a sub-species of *Galago senegalensis*. According to W. L. Sclater, 1900, (Page 23),

"This little Lemur is closely allied to the West African form with which it has frequently been confounded, but an examination of the two species (*Galago senegalensis* in Paris and *Galago moholi* in London) shows that they are really distinct."

According to E. Schwarz (1931), the Galaginae fall naturally into two genera: (1) *Euoticus* with pointed nails; (2) *Galago* with flat nails. *Euoticus* is represented by a single species (*elegantulus*). Members of the genus

¹ The dimensions were given as follows:

Body length	6 inches 10 lines
Tail length	8 inches 4 lines
Head length	1 inch 8 lines
Anterior limbs	3 inches 4 lines
Posterior limbs including feet.	6 inches 11 lines

Galago, however, are numerous and Schwarz divides them provisionally into four species:

1. *Galago crassicaudatus*
2. *Galago alleni*
3. *Galago demidoffii*
4. *Galago senegalensis*²

The Galaginae, because of their long tails and ability to jump, are called "African long tailed Lemurs;" other anatomical details, however, relate them more closely to the short tailed, climbing, loris-like forms of Asia and Africa. The current classification of the Lemuroidea provides for two main divisions, the Lemuriformes and the Lorisiformes (W. K. Gregory, 1916), subdivided as follows:

Suborder Lemuroidea³

Division A. Lemuriformes—all inhabitants of Madagascar

- Family 1. Lemuridae
- Family 2. Indrididae
- Family 3. Chiromyidae

Division B. Lorisiformes—Inhabitants of Asia and Africa

Family 1. Lorisidae⁴

Subfamily 1. Lorisinae

- Arctocebus*—West Africa
- Perodicticus*—West Africa
- Nycticebus*—N. India to Philippine Is.
- Loris*—S. India, Ceylon

Subfamily 2. Galaginae

- Euoticus*—Tropical and subtropical Africa
- Galago*—Tropical and subtropical Africa

Palaeontologically the time and place of origin of the Lorisiformes, unlike those of the Lemuriformes and the Tarsioids, are obscure because of total lack of fossil evidence. Dr. George Pinkley of the American Museum of

² R. W. Hayman (1937) further emphasized the difference in nail structure among the Galaginae. He demonstrated that *crassicaudatus* has concave nail ends while *demidoffii* Fischer, *alleni* Waterhouse and *senegalensis* Geoffroy all have nails which are bluntly rounded at the ends with the exception of *Galago senegalensis inustus* Schwarz. Because this form possesses pointed and keeled nails he is convinced that *inustus* Schwarz should have the status of a new species.

³ The relation of the Lemuroidea to other primates is not the function of this article; however, a brief outline of recent trends in Primate classification may be pertinent.

Classification of
Pocock—Zuckerman
(1918) (1933)

Order Primates

Series 1. Strepsirhini

Suborder Lemuroidea

Div. A. Lemuriformes

Div. B. Lorisiformes

Series 2. Haplorhini

Suborder Tarsioides

Suborder Pithecoidea

Allen-Coolidge modification of Pocock,
Schwarz, Zuckerman, as outlined by R. M.
and A. W. Yerkes, 1935

Order Primates

Division 1. Prosimiae

Suborder 1. Lemuroidea

Suborder 2. Tarsioides

Division 2. Anthropoidea

Dr. George G. Simpson is now (1940) revising his classification, the main outline of which, exclusive of fossil forms, is as follows:

Order Primates

Suborder Prosimii

Infraorder Lemuriformes

Superfamily Tupaioides (Tree or squirrel shrews)

Superfamily Lemuroidea (Malagasy lemurs and lemuroids)

Infraorder Lorisiformes (Lorises, pottos, galagos—no fossil forms)

Infraorder Tarsiiformes (Tarsius and fossil tarsioidea)

Suborder Anthroproidea

While the relation of the Lemuriformes and the Lorisiformes is not changed, the term Lemuroidea is relegated to that of a superfamily instead of the more inclusive one of suborder, and the term Lemuriformes includes the primitive Tupaioides as well. The Tarsioids, as in the case of the Allen-Coolidge modification, are put back once more with the Prosimii.

⁴ Some authors rank the two subfamilies as families, Lorisidae and Galagidae, respectively. In that case no subfamilies are indicated.

Natural History, in the following memorandum to the author (1940) elaborates this statement as follows:

"The occurrence of fossil specimens of the lower primates indicates that in the geologic past the geographic distribution of these forms was singularly different from that of today. Specimens representing the Lemuriformes and Tarsioids (but not the Lorisiformes—lorises, pottos, and galagos), are found in fossiliferous deposits in both Europe and western North America. They are first known from middle Paleocene formations in America, seem to have spread over holartic regions and appear in late Paleocene deposits of Europe. They range through the Eocene, disappear in the late Eocene in Europe but not until the early Oligocene in America. Lower primates are then quite unknown in the fossil record until the appearance of Lemuroids in the late Pleistocene of Madagascar, where they are now confined. And *Tarsius*, living today in the Malay archipelago, is the only surviving representative of the Tarsioids. This leaves a hiatus in the fossil record of nearly two-thirds of Cenozoic time—about forty million years.

"It is furthermore remarkable that the paleontological history of the Lorisiformes is entirely unknown although living forms are widely distributed through tropical Africa and the Indo-Malayan region. It is true that the French Eocene forms *Pronycticebus* and *Pseudoloris* were formerly believed to represent fossil Lorisoids, but more careful examinations indicate that they represent a Lemuroid and a Tarsioid, respectively. There is good reason, from comparative anatomical studies, to believe that the ancestry of Lorisiformes is approximately as ancient as is that of Lemuriformes. It therefore seems probable that during the time when the fossil record of Lemuriformes and Tarsioids was accumulating in limited areas in Europe and western North America, early Lorisoids were living in some other part of the world—possibly Asia or Africa."*

DISTRIBUTION.

Euticus, *Galago alleni* and *G. demidoffi* are forest dwellers, while the six varieties of *crassicaudatus* and ten varieties of *senegalensis* are found only in the savanna country, a type of environment defined by botanists as "grassland with scattered shrubs and medium-sized trees." (J. Chapin, 1933, page 103). According to Shortridge (1934), typical *senegalensis* and other races of the species range through Africa to as far north as Senegal, Nigeria, French Equatorial Africa, the Southern Soudan, Gallaland, and Somaliland and as far south as Inhambane in Portuguese East Africa, but apparently not south of the Southern Transvaal. According to Sclater (1900), Schwarz (1931) and Shortridge (1934), the subspecies *moholi* is widely distributed over eastern, southeastern, southern and southwestern Africa, in the north at least as far as the Tabora district in Tanganyika Territory, possibly extending further northwest.

CONDITIONS OF OBSERVATION.

For the first two winters, I shared the same room with the adult pair of galagos. During the day, the animals were confined in a cage 6×4×4 feet. On a shelf in the cage was a small sleeping box which provided the needed darkness. At night for periods of two to five hours, they were liberated and given the freedom of the room for exercise. A shaded light made observation possible without distress to the animals. By placing food on their feeding shelf, they were finally coaxed back into the cage. While sharing a room with a pair of galagos had obvious disadvantages to the observer, nevertheless, it offered the surest method of obtaining detailed data throughout their active period. During the exercise period, all damageable articles were covered with sheets. At frequent intervals the walls of the room were washed down.

* According to Dr. W. K. Gregory the removal of *Pronycticebus* from the Lorisidae to the Adapidae by Dr. G. G. Simpson (1940) deprives the Lorisoids of any known early Tertiary representative.

From June to September, the galagos were removed to the country, where they enjoyed the complete freedom of a screened-in porch 10×14 feet, adjoining my room. As usual, they slept in a sleeping box on a shelf. Several times each night their activities were checked.

The birth of the young galagos occurred in the second spring, April, 1939, in the apartment room, under the most favorable conditions for continuous observation.

The third winter, when the young animals were half-grown, the inconvenience of caring for so large a family made advisable their transfer to a 10×7 feet partitioned section of a heated greenhouse on the roof of Barnard College, Columbia University. While conditions now prevent a constant watch, some record of activity is made at varying intervals, at least three times each night, twice by myself and once by the night watchman.

In the daytime the animals sleep fairly continuously. A darkened and elevated recess in the cage, greenhouse or porch protects them from the sunlight. Their quarters are kept scrupulously clean by frequent scrubbing.

In both the greenhouse and the screened-in porch, small growing trees planted in tubs have been provided, as well as horizontal and vertical round, wooden, exercise bars. One side of the porch is screened by half-inch meshing, large enough to admit moths, the galagos' favorite fare. The moths and other insects are attracted by a light with a reflector situated in the enclosure.

Full-sized doors leading into both the greenhouse enclosure and porch make it convenient for visitors to enter and watch at close range the behavior of the galago family.

The *Galago s. moholi* seems to be hardy. It can tolerate a wide range of temperatures from summer heat of more than 90 degrees in their sleeping box to as low as 40 degrees on a cold winter night.

FUNCTIONING OF THE STRUCTURES CHARACTERISTIC OF THE GALAGO.

It is my purpose at this point to supplement the outline of the known features of the adult *Galago s. moholi* by further details based on my own observations of the functioning of the outstanding structures which differentiate this form. From time to time when possible I have attempted to compare these structures with those reported of closely related lemuroids, as well as with *Tarsius*, which, while not so closely related, displays many interesting similarities and differences.

The Head.

a. Facial Expression. b. Lips. c. Nose.

The galagos, like the Lemurs, are extraordinarily expressionless—"notoriously blank," as S. Zuckerman has expressed it. They cannot (A. Smith to the contrary) make grimaces or even wrinkle the brow. They can merely stare or droop their lids, move the ears and open the mouth wide enough to expose the teeth.

This lack of facial expression is due in large measure to the immobility of the upper and lower lips. There are two reasons for this condition: 1. the middle of the upper lip is bound by the frenulum to the underlying premaxillary area; 2. the lack of development of the labial and nasal muscles of the facial field. Ernest Huber 1931, (page 28) who has made an exhaustive study of facial muscles of mammals and primates, states that:

"The facial muscles of the Lemur play no role as musculature of facial expression. Indeed we can hardly speak of facial expression in the Lemur."

In common with all other Lemuroidea and many mammals, the galago has a moist, glandular rhinarium with crescent-shaped nostrils, which E. Geoffroy-St. Hilaire (1812) and R. I. Pocock (1918) call strepsirhine. This structure extends into the labial area and becomes the philtrum, or median, attached part of the upper lip. Maxillary portions of the upper lip which are covered with fur may terminate on either side of the naked philtrum as in the case of the lemurs, or, as in the *Galago s. moholi* (Pocock, 1918, and J. D. Boyle, 1932) may meet in front of (over) the labial portion of the rhinarium, a deep groove remaining to show the line of union. In this way the upper lip is completely bounded by fur (Pl. I, Fig. 1).

When the *Galago s. moholi* is angry and prepared for defense or offense, it opens the mouth so wide that the labial area is stretched and the canines and premolars exposed. There is no ability to draw up the lip in a snarl or to make grimaces of any sort. The enlarged photograph (Pl. I, Fig. 1) of the face of one of the galagos shows the preliminary stage of rage. The mouth is partially opened though not wide enough to show the teeth. The eyes are focused on the cause of irritation located just above its head.

The sense of smell of the galago as of other Lorisiformes is well developed and still serves a more important function than in the higher primates.

Le Gros Clark (page 177) states that:

"In general there is a close correlation between the degree of complexity of the turbinate system and the acuity of smell." . . . "In Lorisiformes the first ethmo-turbinal is very large and actually covers over the maxillo-turbinal while in Lemuriformes it is much smaller."

The presence of a relatively large olfactory lobe in the brain is additional evidence that the galago and the lemurs, in common with the lower mammals, retain their dependence on the sense of smell.

The galago places great dependence upon its sense of smell. Curiosity is satisfied through this means. Any strange person, or object, is first thoroughly smelled, or food is approached nose first unless it is food-on-the-wing, when it is seized first and smelled afterwards. The facial tactile vibrissae, or "whiskers," around the nose are said to be closely associated with the sense of smell. Though they are not as well developed as in the genus *Lemur*, they are still evident in some degree. The mystacial, mental and genal, are present though more delicate and less obvious (Pl. I, Fig. 1) than in *Lemur*. According to Ernst Huber (pages 22-23), among the Lemurs:

"The mystacial and mental vibrissae jointly with the rhinarium, a highly sensitive patch of mucous membrane at the tip of the snout, subserve the tactile sense of the latter, which is closely associated with the sense of smell. . . . This sense, which plays an eminent role in the life of the primitive, terrestrial mammals, is of subordinate importance in the primates and has already become deteriorated in the Lemuroidea. Undoubtedly in connection with their adaptation to arboreal life, the sense of touch, with the aid of the facial tactile vibrissae, is, however, of the greatest usefulness to these primitive primates in their life amidst the branches of trees. Indeed, the sense of touch together with the highly developed sight and keen hearing are the guiding senses of the lemur."

In my judgment the sense of smell should be added as an important guiding sense.

The mouth and nose of the *Tarsius* are strikingly different from those of the galago or other lemuroids. There are no crescent-shaped nostrils with moist rhinarium extending into the upper lip. Like higher primates, the nostrils are oval and there is only a remnant of the moist area about these apertures, a condition which Pocock (1918) considers of such fundamental importance that in the classification of the primates he uses this feature as a basis for primary subdivision. He calls the lemuroids "Strepsirhini" and all other primates including *Tarsius*, Haplorhini.

d. Eyes.

The large, round eye bulges forward, giving a conspicuously rounded appearance to the surface. In the daylight the entire surface of the eye is colored a homogeneous light brown. Since the whole visible portion of the eye is covered by the rounded, transparent cornea, no portion of the sclera can be seen. The pupil, as A. D. Bartlett (1863) observed long ago in the case of *Galago crassicaudatus montieri*, is vertical (Pl. I, Fig. 1), a condition common to Lemuroidea and to many nocturnal mammals. *Tarsius*, however, differs from the galago in that the pupil is horizontal. A recent photograph which appeared in Collier's Magazine (August, 1939) of Professor John Fulton's two living specimens at Yale University, shows the pupil in the light as a horizontal slit, although in their other respects the eye is strikingly similar.

Under the hand lens, the vertical pupil of the galago eye appears to be slightly rounded at each end and somewhat wider in the center. Fine dark lines radiate from the rim of the slit into the iris. The spacing of the lines seems to vary with the intensity of the light. When the light is bright and the slit narrow the lines seem crowded together. In a dimmer light, the slit is larger and the radiating lines farther apart. A slight scalloping of the edge of the slit between the lines is apparent. At night in a dim light the iris opens to a prodigious extent, leaving only a small portion of the brown visible as a rim. By reflected light the pupil is brilliant orange (like the lemur). The eyelids, which are kept wide open, have lashes on the rims visible on the upper lid of the right eye in the enlargement (Pl. I, Fig. 1). It is difficult to see the lid except when the animals are sleeping. We succeeded in getting a photograph of a form with extended lid after it had been temporarily blinded by a flash-light bulb which it was examining when the light was discharged. The photograph clearly shows the upper lid covering the major portion of the bulging eye (Pl. II, Fig. 3).

The eye is so large that the extrinsic muscles are unable to move it. In compensation the head moves flexibly as a whole in quick motions from side to side and sometimes in an ellipse. The head may be bent to the side at such an angle that one eye is placed almost vertically above the other. It may also turn practically 180 degrees so that the nose is directly over the spine and, as Cooke (1939) has noted in the case of the *Tarsius*, the animal frequently moves its head in this manner to look upward. The galago does this when it is clinging to some vertical or inclined branch or when clinging upside down to a horizontal branch. The ability to turn the head in a direction opposite to that which the body "faces," a convenient adaptation for any perching animal, relieves the necessity of lessening the hold on the perch.

e. Ears.

The membraneous ears are large and almost naked on the inner and outer surfaces except at the rim where there is a sparse covering of fur (Pl. I, Fig. 1). The inner surface, as E. Geoffroy-St. Hilaire first and A. Smith later noted, is marked by four transverse ridges which seem to terminate in an outer vertical ridge (Pl. I, Fig. 1). An outstanding galago peculiarity is the ability not only to move the ear as a whole forward, laterally or upward, but also to fold the pinna along the ridges somewhat like an accordion, throwing its outer tip back over the upper transverse ridge. In addition to the accordion-like folding, the whole pinna may be further pressed back against the head so that all evidence of large projecting ears disappears.

The ears of the galago are perhaps its most expressive feature. They move singly or in unison in the direction of the least unexpected sound. When looking over a new object or person the ears seem as alert as the nose and the eyes. In sleep there is a tendency to fold the pinnae along the

ridges (Pl. II, Fig. 2, lower center) and in anger there is also some tendency to corrugate them (Pl. II, Fig 2, right). The final flattening of the folded pinnae against the head occurs when the animal enters an enclosed space. When seeking food which I have placed in the cupped palm of my hand, the galago thrusts forward both head and hand, invariably flattening the ears against the sides of the head. This is an admirable device for the protection of large and delicate ears from the dense foliage and perhaps also from the perils of battle.

Tarsius ears, though much smaller relatively, seem to be of a similar type, according to Ernest Huber (page 27), and the musculature which moves them is highly developed.

f. Jaws, Teeth and Tongue.

The round head and short face are characteristic of the several varieties of *Galago senegalensis* and *demidoffii*. The upper jaws and the snout with the crescent-shaped nostrils do not project forward to the extent that they do in *Galago crassicaudatus* or in the Malagasy lemurs. The lower jaws, which are also short, bear the usual two pairs of procumbent incisors flanked by the elongate modified canines that project forward almost horizontally and have been known as the "tooth-comb" of the lemurs. The teeth of this incisor-canine complex of the lower jaw converge at their tips so closely that, as M. Russell Stein (1936) points out in the case of the true lemur, the term "comb" is probably inaccurate. "Scraper" is perhaps a more accurate term. The* first premolar of the lower jaw has become modified into a somewhat caniniform structure though less so than in the true lemurs. By working against the canine of the upper jaw, this tooth acts as a shearing or a nipping apparatus. The remaining molars and premolars are more advanced than those of the typical insectivorous lemurs as Le Gros Clarke (1934) has recorded, since the† third premolar of the upper jaw is more molarized and the first two molars are quadri-tubercular, having one more cusp than those of the typical lemurs. The two pair of upper incisors, separated by a space in the center, are so small that it has been suggested they are functionless. Because of the strong roots possessed by these teeth in the case of the true lemurs, M. Russell Stein questions this idea. Can these upper teeth function with the lower horizontally placed incisor-canines or can they be used in any other way? I can confirm the statement made by Stein that the upper incisors are functional. The galagos in my possession will frequently bite when handled, and several times the bite has been sufficiently severe to leave a clear imprint of the tooth marks. In each instance the imprints of the upper canines and the two pair of incisors which lie between have been evident, as well as the imprint of the pair of lower caniniform premolars and the scraper itself.

The question of the use of the incisor-canine complex or scraper is an interesting one. In an article published in 1939 on "The Feeding and Grooming Habits of the Galago," I attempted to show that the scraper was used as a toilet or grooming structure. Since then I have experimented further to determine whether, as suggested by Stein, this device is ever used for scraping fruits and biting off leaves. On placing a pear upon the feeding shelf, I found that the scraper was never used. The galago attacked the pear with the canines of the upper jaw and after making a hole in the skin it then inserted its long, thin tongue into the aperture and licked out what it wanted from the interior. Again, when a tree was placed on the porch some of the smaller branches were bitten off. In each case the canines and the first premolars of the lower jaw were used, never the incisors. The general conclusion is that the scraper of the lower jaw, in the case of the galago at least, is essentially a grooming implement though it has not yet been proved that it may not act upon occasion as a food-scraping device.

* Homologous with P₂ of the primitive mammalian dentition.

† P₄ superior of the primitive mammal.

The long, thin tongue, like that of the true lemurs, is used for licking and lapping. Although of somewhat limited movement, its action is straight forward over the incisor-canine complex of the lower jaw which acts as a trough. The tongue is long enough to reach the moist rhinarium over which it can curve.

It is interesting to note that *Tarsius* also uses its tongue as a licking and lapping structure.

The Limbs.

a. The Hand and its Action.

It is well known that the fourth digit of the hand among the Lemuroidea is the longest of the five. In this characteristic, they differ from all other primates, including *Tarsius*, and from Mammalia generally where the third digit is the longest. The hand digits of *Galago s. moholi* as a whole are relatively long. The thumb is short and separated from the index finger by a considerable interval; the index finger is also short and separated from the third digit by a less marked interval (Pl. III, Fig. 6). The third and fourth fingers grow progressively longer with the fifth somewhat shorter. The last three digits are more closely placed (Pl. III, Fig. 4).

In 1838 W. Ogilby demonstrated at a meeting of the Zoological Society of London the structural peculiarities of the hand of a living specimen of galago, then known as *Otolencus garnetti*. This peculiarity consisted in the partially opposable character of the index finger of the hand. It was shown that the thumb and the index finger could be used as a unit to grasp one side of a branch and that the remaining three fingers were used on the other side, much as the koalas would do. Mr. Ogilby remarked, "The anterior index finger in all the 'inferior' Lemuroidea is weak and powerless and it has the same tendency to divide with the thumb instead of with the other fingers in the rest of the galagos as well as in the Nycticebi, the Microcebi, the Cheirogalei, and Tarsii whilst in the Potto it is reduced almost to a tubercle." In watching the action of the anterior digits of the galago, I find that my observations do not agree with Mr. Ogilby's in all respects. The index finger lies almost midway between a large space which separates the thumb from the third finger (Pl. III, Fig. 6) and, in grasping, it is just as likely to be found with the third, fourth and fifth digits as with the thumb. Its disposition depends somewhat on the size of the object grasped. If it is small enough to fit in the space between digits two and three, digit two is then likely to be found on the side of the thumb (Pl. I, Fig. 1); if, however, the object or branch is large, the index finger then lies almost between the two. In any event the index finger is so small that its effectiveness as an opposable structure is very limited.

An interesting feature of the digits of the hand is the size of the individual phalanges of all but the thumb. In each instance the proximal phalanx is long and the second one is slightly less so while the third or distal phalanx is minute and very little larger than the nail. The relative length of the phalanges is an admirable adaption for grasping limbs and small branches of trees. Two peculiarities, however, are evident because perhaps of the elongation of the proximal elements. 1. When the galago places its hand upon a flat surface, the palm of the hand with its pads rests flat upon the surface; the digits, however, are not extended straight forward but are flexed, the pads on the distal ends of the digits alone resting upon the surface. There seems to be a flexure at the knuckles which permits the raising of the proximal phalanges away from the ground. Furthermore, the joints between the first two phalanges instead of pointing directly upward are bent to the side, even the index finger may be involved (Pl. III, Fig. 4). A recent motion picture of Dr. John Fulton's live *Tarsius* shows the same flexed condition of the digits when the hand rests upon a flat surface. 2. A

second peculiarity is to be noticed when the galago grasps a piece of food. Among the other primates the digits flex over the object at the knuckles and the palm of the hand is involved. In this instance, however, the proximal phalanx of each digit (the longest) remains straight on a plane with the back of the hand, and the grasping is done by flexing the two distal phalanges over the proximal. The thumb acts in opposition and the palm is not covered by the digits (Pl. III, Fig. 5).

b. The Foot and its Action.

The enormous hallux of the foot is widely separated from the other four toes which act as a unit (Pl. III, Figs. 6, 7; Pl. IV, Fig. 8). The fourth digit, in this instance like that of *Tarsius*, is again the longest of the five, while the second toe is short and, as in the case of all other lemuroids, bears a flexed claw (Pl. IV, Fig. 10). All the other digits of both hands and feet have nails which are flat with relatively straight edges (Pl. III, Fig. 4) (A. Smith, 1836). The great distinction of the foot of the galago as compared with other lemuroids is the extraordinary elongation of the navicular (scaphoid) and the calcaneum first noted by E. Geoffroy-St. Hilaire. The digits and distal portion of the metatarsals are the only elements which rest upon the ground. The proximal portion of the metatarsals are well as the tarsals are always off the ground; in fact, as Pocock (1918) has admirably shown, the ventral aspects of this area of the foot are covered with fur and are usually raised some distance from the ground (Pl. III, Fig. 7; Pl. IV, Figs. 8, 9). The total length of the foot is 2 to 2¼ inches, about half the length of the hind leg. It is this unusual lengthening of the tarsal segment which makes possible the extraordinary leaps characteristic of this form.

c. Volar and Solar Pads.

The well developed pads on the palm and the sole of the galago are quite primitively disposed in a characteristic manner (Pl. III, Figs. 6, 7). There are two proximal pads, the thena and the hypo-thena, and four distal interdigital pads. In both hand and foot the thena pads tend to fuse somewhat with the first interdigital and the hypo-thena with the fourth interdigital. The interdigital pads of the foot are not all of equal size, the third being much smaller than the others.

Pads also are to be found on the toes and fingers (Pl. III, Figs. 4, 6, 7). Along each digit between the palm or sole, and its tip, a long, thin pad is found which enlarges at the tip. Although this enlargement or pad is not equal in size to that found on the tip of the *Tarsius* digits, it is, however, an effective surface. The big toe has a broad distal and proximal pad. The first interdigital which follows is a round, conspicuous pad, protruding beyond the confines of the digit and the sole (Pl. III, Fig. 7). Oblique papillary ridges are to be seen on the pads. Dr. Charlotte Wolff (1938) has found "unique scale-like roughness" in two species of galago (*moholi* and *crassicaudatus*) as well as in *Loris* and in the genus *Lemur*. She describes them as more expressed on the sole than on the palm and are found in the center of the palm and sole and on the lower phalanges but not on pads. She also finds that all the terminal phalanges have tactile corpuscles.

d. The Hind Limb and Its Action. aa. Climbing.

bb. Moistening of Pads. cc. Jumping.

Not only is the hind limb very long, but its strength is also enormous. The animal can hold on by its hind feet alone (Pl. IV, Fig. 9); it can lower itself down into a jar, or suspend itself freely, head downward. By the power of the muscles of its hind legs, combined with the strength of the muscles of the foot, it can lift itself once more to its original position without the aid of the anterior limbs. One of the tamer individuals born in captivity will

grasp a finger of my hand by the huge opposable big toes and the other digits of its hind feet and will let itself down into a paper bag suspended from my hand. The strength of the grasp of the large toe and the other digits upon my finger seems out of proportion to the size of the animal. There seems also to be a particular pressure exerted by the hallux and the inner surface of the sole of the foot. This is the area where the interdigital suction pads are especially well developed. The added pressure exerted at this point flattens out the adhesive pads and makes them more effective as a clinging device. The use of the pads as an aid to clinging is shown in the illustration (Pl. III, Fig. 6). This photograph was taken from the inner side of a glass door on the outer side of which the galago was clinging. The pads of the hind feet press against the flat surface of the glass, obliterating the spaces between the pads and show the way in which the large pads of the big toe and the first interdigital adhere firmly to the glass surface. This explains the animal's ability to climb up and down any perpendicular surface which offers an edge, such that the thumb and great toe can get a purchase. The galago always descends head first.

Grasping and climbing are facilitated not only by the elongation of the fourth digit over that of the third and by the strength and opposability of the very large, widely abducted hallux, but also by the moistening of the pads of both hands and feet. The latter action is one characteristic of the galago which is accomplished in a definite way at frequent intervals throughout the active period, whether climbing or sitting still. By placing the palm of one hand under the urethral aperture, the animal collects a drop of urine. It then rubs the moistened palm of the hand on the sole of the foot of the same side, repeating the action with the other hand and foot. This automatically moistens the naked surfaces of the pads and renders them more effective surfaces of adhesion. No one seems to have recorded this action except E. G. Boulenger, who, in his popular book, "Apes and Monkeys," states that the galago has "a strange habit of moistening the palms of the hands and the soles of the feet at frequent intervals when climbing" (p. 206), although he gives no clue as to the way in which this is accomplished, nor does Mr. Boulenger record this as a common practice even when the galago is sitting quietly.

The galago, essentially a hopping and jumping animal, normally perches in high places (Pl. IV, Fig. 8). Although it uses all four feet for climbing and usually for perching, it does not normally run or walk on all fours. The structure of the posterior limbs is responsible for the characteristic hopping and leaping motions. When jumping on a horizontal plane this form can span as much as six feet. Vertically it can spring upward as much as five feet, landing on a perch with unerring precision. When jumping downward diagonally from a higher to a lower perch much greater distances are covered.

As an example, one of the adults sprang from the balcony rail of a studio room to the top of an open door in the room below, a distance of twenty feet. Although the thickness of the door was only two inches, the landing was made with precision. When, and rarely, the adult galago makes an imperfect landing, it seems to be due to an insecurity of grasp rather than inaccuracy of gauging distance. The speed and extent of the jump is particularly great in this variety and exceeds that of the larger species (*crassicaudatus*).

The preliminary stages of jumping are expressed by a crouching of the body. The hind feet are placed with heels together off the ground and toes out. The spring is made with great speed and the feet are kept in the same relative position as attained when taking off, though somewhat farther apart. From a front view of the approaching animal the soles of the feet can be seen slightly up-raised. The heels are no longer touching, but may

remain relatively close together. This explains the ability of the galago to jump even though his legs are bound together above the heel. Donald Carter, in his field notes of his trip in South Africa (1938), recorded the following:

"Balovale, September 4.—A native brought us four (two males and two females) galagos alive in a gourd. Upon removing the wad of grass which served as a plug for the hole, one of the animals jumped out landing on the table. From there it jumped a good six feet to one of the posts supporting the tent and without a moment's hesitation he took another jump to the trunk of a small tree under which the tent was pitched. This jump must have been eight feet. Up this tree he scrambled and hid among the boughs. I sent a boy up the tree and with some difficulty the animal was dislodged and jumped to the ground where he was pounced upon by about five small boys who were waiting underneath. It was not until he was retrieved that I noticed that the animal had his two hind legs securely tied together at the ankles by a piece of grass. Hampered as he was he easily and gracefully made these two jumps landing both times where he had planned."

Before taking off to a new position the eye of the galago always gauges the distance to be covered quickly and carefully. The jump to a new perch may involve a diagonal or backward leap. The animal, however, always manages to face the new perch on landing, though it may mean a 180 degree turn in mid-air.

Occasionally the galago will stand up straight, balanced on its toes with the hind limbs not flexed. In such a position, it immediately becomes quite tall (11 inches) and of a short-waisted appearance because of the relative length of the hind legs and feet (Pl. IV, Fig. 10). The tail, from eight to ten inches long and somewhat bushy at the end, serves as a balancing structure when jumping or when standing upright. In the latter action the tail moves up and down to help maintain balance. It may also serve to protect the eyes from the light while sleeping, though it is more frequently curled over the breast at such times. While the tip of the tail continues to be slightly curled when the animal first awakens, it straightens out as soon as the galago becomes active.

The Reproductive Organs.

R. I. Pocock in his admirable article, "On the external Characters of the Lemurs and Tarsius," (1918) has described in detail the structure of both male and female reproductive organs of *Galago senegalensis*, *crassicaudatus* and *montieri* as well as other forms of the Lemuroidea. The presence of baculum and spines on the penis seems to be a condition common to all male Lemuroidea but invisible of course in the living state.

The male in conformity with the lemuroid type (except the genus *Lemur*) has an external scrotum covered with fur. The penis is relatively short with a long, inverted tip. Recently, just before the period of heat of the female, (December, 1939) I saw the everted tip of the penis. Its shape differed from those described by Pocock for *crassicaudatus*, *senegalensis* and *demidoffii*. The everted portion was a relatively narrow cylinder, over an inch in length, which expanded suddenly into a wide bulb at the tip. As I watched, the bulb suddenly contracted with startling speed to almost the dimensions of the rest of the penis. As I was fully six feet away from the cage when I saw this structure, it was not possible to see whether the bulb after contracting formed a structure comparable to the "frill" which Pocock described as present in the case of the tip of the penis of *Galago crassicaudatus*.

The female *Galago s. moholi*, as Pocock has shown in the case of galagos of other species, possesses a long, pendulous clitoris, at the terminus of which is the urethral aperture. This peculiarity makes it difficult to determine the sex of the individual as the structure resembles superficially a penis in shape and length. The inverted tip of the penis and the presence of the permanent scrotum, however, differentiate the male.

DISPOSITION.

The galago is a very quick and nervous animal, which responds to the slightest unexpected noise or movement. It will crouch in terror and then spring away from the direction of danger with lightning speed. Like most lemurs, though easily tamed, it is somewhat truculent and uncertain in its relations to humans. It resents handling. Balancing on its haunches, it will hurl itself forward, striking out first with both hands like a diminutive prize fighter, and then grabbing hold of the object. Since the nails are flat, this is a harmless gesture. But this attack is followed by a quick forward thrust of the head and a very nasty bite may be inflicted by the sharp canines and the first premolars of the lower jaw. At times even the scraper is involved. During the attack the animal utters a querulous chatter. The truculence of the galagos seems to be directed solely toward humans. I have never seen them fighting among themselves. Even the young ones are independent and dislike handling, though they will tolerate a gentle rubbing of a finger along the jaw or behind the ears. The presence of several people does not disturb them providing no quick movement or noise is made. Completely fearless of humans, the twin galagos born in captivity enjoy jumping on a shoulder or sitting on the top of someone's head.

The galago is as inquisitive as a monkey. Unlike that animal, however, curiosity manifests itself by smelling instead of handling the strange object. The galago will investigate the face and wearing apparel of even a total stranger. Anything new brought into the cage or enclosure is always smelled carefully.

I have attempted to show in another article (1939) that *Galago crassicaudatus*, when alone, and dependent upon humans for companionship, was a relatively affectionate animal which treated me much as it would a fellow galago. Without doubt the *Galago s. moholi* would be more demonstrative to humans were it dependent on them for companionship. It cannot be said, however, that this group of four display any real affection beyond their own circle. Their interest in me, I suspect, is due to the food I supply. As a group they play together in utmost harmony. They will pursue each other, roll about, and playfully grapple. At times they will hang suspended from a horizontal stick by their hind feet the while beating at each other with their free arms like two inverted pugilists. At feeding time it is a question of each galago for himself, although when the babies were beginning to eat and for a few months thereafter, their mother would sometimes give up part of her catch to a hungry young one who had jumped up beside her to help itself. Food in the possession of other galagos is much more attractive than any food in a plate. They will spend a great deal of time pursuing succulent morsels in the hands of one of their companions, even though similar morsels may be present for them. There seems to be no resentment on the part of the pursued if its prize is taken from it. The galago immediately proceeds to recapture the diminishing tid-bit.

BEHAVIOR OF THE ADULTS.

Although the behavior recorded in this section has been observed while the galagos were in the state of captivity, nevertheless the conditions under which they were kept have approximated, so far as is possible, their natural environment. Hence, I am justified in feeling that this general behavior does not differ fundamentally from that of the wild state.

Feeding.

Observations of this variety of *Galago* confirm the recorded statements that while they are insectivorous, they eat other things as well. Live moths,

grasshoppers and meal worms are great favorites. Milk, a constant in their diet, has never been refused. Vitamin B and cod-liver oil have been added occasionally to milk, especially after the birth of young. Sweetened fruit juices and melted ice cream are relished. Although water has frequently been placed before them, there is no evidence that they drink it. They will eat various kinds of thinly sliced raw vegetables and fruits at any time; more freely in the winter months when insects are difficult to obtain. They will also eat buttered bread or bread spread with honey in which wheat germ meal and rice coating flour are mixed. When cut flowers from the garden are available, such as bergamot and honeysuckle, they will bite off the heads, pull apart the petals and chew at their bases.

In the case of live food, as Geoffroy (1796) first recorded, the galago fixes its gaze intently on the insect. It never attempts to jump at it in mid-air; instead, it leaps up to a perch close beside the insect. Then holding on with its hind feet, the galago reaches out and grabs the moth with one or both hands. After putting the live moth in its mouth, it jumps away to a secure perch somewhat removed from its companions. Sitting up and holding the insect in one or both hands and closing its eyes to protect them from the frantic beating of the insect's wings, the galago begins at the head and consumes all but the wings. This is the same procedure which Cooke has recorded in the case of the *Tarsius* (1939). The wings are discarded by using the tongue to shove out over the scraper, which thus seems to be passively used as a trough. I have frequently placed moths in a wide-mouthed jar covered with a loosely fitting lid. The galagos quickly learned to push off the lid by using the tip of the nose. Standing up, stretched to full height, one will peer in and leap to the rim with all four feet bunched together. Then liberating the front legs but still holding on with the hind feet, the galago will dive in head first, locate and grab the insect with one hand and haul itself back by the power of its hind legs without loss of balance. Even when there is plenty of food flying about, the galagos tend to grab it from each other.

Vegetables and other inert food are always smelled carefully before sampling. If acceptable, the animal takes a small piece directly in the mouth, jumps away, and holding the morsel in one or both of its hands, bites off what it wants and drops the rest. Liquids are usually lapped up by the long tongue; at times, however, the hand is plunged into the fluid and subsequently licked dry.

Feeding takes place regularly. In the morning milk is placed in a shallow container close to the sleeping box. By the end of the day most of this has disappeared. At about 8 o'clock in the evening various foods and a second supply of milk are provided and left available throughout the night. The animals which have been active for some time are now hungry. They rarely consume a whole piece of vegetable or fruit; their habit is to take a few bites and drop the rest. In the morning the enclosure is strewn with fragments.

Throughout their active period, fecal elimination is very plentiful; the more so when they first become active at night. Urinary elimination is also plentiful and frequent, and usually independent of moistening the foot-pads, which has already been described. Though they rarely soil their sleeping box, they seem to have little further concern about the place for elimination. If handled during the day, they express fear or nervousness by immediate urinary and fecal elimination.

Grooming.

The galago is an unusually clean animal. Even its hands when soiled by food or foreign substance are carefully licked clean. General grooming involves the frequent use of the procumbent scraper, the tongue, and the oc-

casional use of the claw which serves as a scratcher for such spots, otherwise inaccessible, as behind the ear.

The chief grooming instrument, the procumbent scraper, long called the "comb," is used by the galago in vigorous action on his own pelt or on that of one of his companions. This action is a series of quick thrusts through the fur deep down to the integument. By this scraping action the animal can dislodge and remove any dead skin or foreign substance in the pelt (Lowther, 1939). The tongue completes the process of grooming with a thorough gentle licking.

Begun on first awakening, before the start of much activity, the grooming is repeated for short periods frequently during the active period. Grooming may be a mutual operation. I have seen two galagos grooming each other simultaneously; and two young ones may work on one of their parents at the same time. As for the action of grooming on the part of a galago of another species (*crassicaudatus*) with no companions other than myself, I have had personal experience. This animal frequently perched on my arm or hand and vigorously dug into my integument with its scraper as though I were a fellow galago. The intensity of the digging and scraping made it clear that any foreign object in the fur of a galago could be effectively removed. While the present variety of galago has not bothered to attempt much grooming of their mistress, the young ones occasionally have repeated the action of the former galago, particularly after licking off some sweet morsel adhering to my fingers. At times they have used the scraper perhaps to get off the last remnants of sweetness.

Calls.

The galago has several notes characteristic of different conditions, clearly differentiated but difficult to describe. 1. The alarm note; a shrill sound on a high pitch, which starts somewhat like a chipmunk's scolding note, though shriller, but which ends in a whistle. This note quiets the group into frightened stillness. 2. An automatic cry, the cause of which is unknown, and which may continue for an hour. It is a piercing noise with two pitches, high and low. While the animal is making this noise it will continue its activity, eating and jumping. It does not affect the others. 3. The low clucking note like the brooding hen, but on a lower register; used when annoyed. 4. The sex note, used by the male when pursuing the female. This is a soft questioning sound of two notes. 5. The conversational note; when separated, both male and female call to each other. This note is softer than the sex note but has the same two pitches, high and low. 6. A chattering note used by the female as an expression of annoyance at the attention of the male. 7. The maternal note; a very gentle, soft, caressing sound, used by the mother when talking to the young in the nest. 8. The squeak of the young; suggestive of young mice. It might possibly be called a squeaky chirp.

Sex Behavior.

The female of this form will accept the male only during periods of oestrus, which may last as long as five or six days. At this time she has a colorless discharge which perceptibly excites the male. He constantly smells her genitalia and just before the act of copulation the male is likely to lick the female with his long tongue. During the period of sex activity copulation has been observed to occur three or four times a night and it has also been seen in the morning when the animals would normally be sleeping. During the long periods between oestrus, the male continues his interest, although the female refuses to accept him. As he pursues her around the cage or enclosure, he utters a soft, plaintive call which I have described as the

"questioning sex note." At times the female merely keeps one jump ahead of the male and seems undisturbed by his attentions. If, however, they are continued for any considerable time, she finally turns upon him in annoyance with a chattering cry. This usually effectively discourages his attentions. Once, however, I saw the female become so angry, after chattering at the male without effect, that she turned upon him with such fury that he took to his heels in alarm. Generally speaking, the adult pair is a friendly and affectionate couple. They are frequently found perching side by side, grooming each other, wrestling and at times embracing (rubbing noses). During the period of pregnancy the female's disposition became far more truculent. The continued attentions of the male were repelled with increasing vigor and shortness of temper.

Nesting Habits.

The galago in the wild is in the habit of nesting in the hollow places among the tree-tops, according to E. Geoffroy-St. Hilaire, Pitman, Shortridge, and others.

E. Geoffroy, 1796:

"Ils nichent dans des trous d'arbres où ils préparent à leurs petits un lit qu'ils tapissent d'herbes."

Pitman, 1934:

"I have often come across the leafy beds these animals prepare for expected offspring at the bottom of hollows in trees."

Shortridge, 1934:

"*Galago moholi granti* is strictly nocturnal, sleeping during the day in hollow trees where it may generally be taken in small family parties."

In captivity, I have found that these animals show a tendency to tear up bits of available paper and to carry them into the sleeping box. While on the porch where a growing apple tree is situated, they bit off the ends of leafy twigs and carried these to the box up under the eaves of the porch roof. They would also gather bits of string, wool, heads of flowers and almost any other small soft object which happened to be loose. Just before the birth of young ones, the female was particularly active about the construction of a lining for the sleeping box. The galagos obviously prefer a darkened area in which to sleep during the day. Whenever a box was given them they used it rather than some secluded corner of the cage or porch.

F. Wood-Jones, p. 116 (1929) states that:

"Nest-building is a habit that is widespread among the Lemurs, and it occurs both in the species found in Madagascar, and in those living in continental Africa and in Asia. The curious Aye-Aye "*Chiromys*" builds an elaborate nest which has been described by Baron as a structure about two feet in diameter and entered by a hole in the side. Shaw has described the nest of "*Chirogale milii*" as consisting of "leaves and Dry Grass," and that of "*Microcebus smithii*" as resembling a bird's nest."

BREEDING SEASON AND PERIOD OF OESTRUS.

Galago Activities.

When received in September, 1937, the female was immature. Ten months later (July 19, 1938), she experienced the first onset of oestrus. She did not become pregnant, however. After an interval of five months a second period of oestrus occurred (December, 1938) which resulted in the birth of twins four months later (April 14, 1939). Oestrus did not re-occur until

December 10, 1939, although the young stopped nursing sometime in July. At intervals of six weeks three additional short periods developed, and a fourth occurred twelve weeks later. A table of these data follows:

	Length of oestrus	Result
Female matured July 19, 1937	5-6 days	no fertilization
Second oestrus Dec. 15, 1937	5-6 days	twins (born Apr. 14)
Third oestrus Dec. 10, 1939	at least 3 days	no result
Fourth oestrus Jan. 22, 1940	at least 3 days	no result
Fifth oestrus March 7, 1940	?	no result
Sixth oestrus May 29, 1940	3 days	no result

** Oestrus recurred Dec. 7, 1940. See Appendix, page 461.

The only conclusions which can be drawn from these limited data are: 1. the period of gestation is four months; 2. a restricted season of sexual activity is indicated. Whether December normally initiates the sexual season in the wild state and the first expression of oestrus in July was atypical, or whether the latter is typical and the shift from July to December is an adaptation of the animals to their new environment, cannot be determined. In any event this evidence still indicates the time for the birth of the young is limited to the period between April and November. 3. It is also evident that like many other forms with a limited breeding period, in the absence of fertilization oestrus will reoccur at intervals, thus establishing the galago as poly-oestrus within the limits of their sexual season.

Comparison with Breeding Habits of Other Lemuroidea.

Zuckerman substantiates the conclusions that the moholi galagos, like the lemurs, have a restricted breeding season. He states that although the records are too few to place any definitive reliance on them, they nevertheless indicate that the breeding season is between April and September, with the majority of births taking place between April and June. He bases these conclusions on the record of seven births of *Galago s. moholi* which have occurred in the London Gardens between 1856 and 1927.

Donald Carter, mammalogist of The American Museum of Natural History, who recently returned (1938) from an expedition in South Africa, has made available to me his field notes and many specimens of *Galago s. moholi*, most of which were taken at Balovale, Northern Rhodesia, on the Zambezi River.

Between August 23 and October 15, Mr. Carter secured more than one hundred adults of which he brought back seventy-two to the museum. Two of the 29 females contained embryos, and one he noticed was nursing young. (He tells me that he did not record whether the remaining females were nursing). In addition to the adults 20 young galagos were brought into camp by the natives. The following is a digest of Mr. Carter's field notes concerning the young taken at Balovale:

August 23	.....1	pair shot, female nursing young
September 4	.....1	female with a single embryo
September 14	.....1	female with two fully formed embryos
September 18	.....2	newly born
September 20	.....1	young
September 24	.....2	young
September 26	.....4	young
September 27	.....3	young
September 28	.....2	young
October 1	.....2	young
October 10	.....2	young
October 15	.....2	young

An analysis of these data reveals that:

1. The relatively uniform dimensions of the adults indicate that they were at least a year old.
2. A comparison of the pelage and measurements of the young in the museum collection with those taken during the growth of the pair in my possession shows that the largest were not more than four or five weeks old.

Zuckerman (1932) states that three births among *Galago garnetti* occurred, one in May and one in June, 1930, and one in September, 1929, in the London Gardens. This corresponds with reports of births in the London Gardens among the true lemurs where only very exceptionally were there records of births outside the period March to June. Zuckerman states that, "All the sixty-six births occurring in the London Gardens Zoo were distributed in the period March to September, sixty-four between March and June, and two in September." Major S. S. Flower (1933) presents additional data which "provide a very good reason for arguing that species belonging to the genus *Lemur* have a demarcated breeding season. The following table showing the months in which 120 lemurs were born in the Giza Zoological Gardens confirms Zuckerman's opinion":

March	26 births	Twins	Triplets
April	42 births	3	1
May	32 births		
June	15 births		
July	4 births		
October	1 birth		

120

From this additional evidence it is conclusively established that the galago, like the lemur, has a restricted breeding season ranging from April to October, but that probably the galago south of the equator is more apt to have young in September and October than the lemur.

Zuckerman (1932) states that, "The breeding habit of the African members of the series *Lorisiformes* appears to be different from that of the Asiatic species belonging to the same subdivision of the *Lemuroidea*. Thus, the few available records regarding births in the genus *Galago* suggest that the animals belonging to this genus may have a restricted season, whereas the Hubrecht data for the slow Loris (*Nycticebus coucang*) prove that this animal breeds throughout the year." According to him, however, its curve of fertility seems to rise toward the end of the year.

Discussion of Environmental Causes of Oestrous Change.

An interesting article written by F. H. A. Marshall (1937) presents evidence that the reproductive rhythm may be influenced by extero-ceptive or other environmental influences, and that the oestrous cycle may be reversed in animals living in temperate climates after transference across the equator. He concludes that "among the insectivores, carnivores, rodents and non-ruminating ungulates with very few exceptions outside the tropical areas breed in the spring or first half of the year in the Northern Hemisphere." Also, "That they react to seasonal changes in a remarkable way is shown especially by those natural experiments in which animals of various species that normally breed once annually have crossed the equator and as a consequence have been induced to have two sexual seasons in one year." Marshall emphasizes the potency of more or less light as an activating factor. He further states that "Tropical and subtropical forms, however, such as antelopes (red and blue duiker) which live under comparatively uniform conditions as regards daylight, may have an extended breeding season or breed

all the year. They do not adjust themselves to the changing conditions of temperature in regard to sexual activity."

Following this analogy, could not the differences between the breeding habits of the lorises and the galagos be accounted for by a study of differences constant in their normal habitats? Since all these forms are nocturnal and tropical or subtropical, the value of more or less light as a breeding factor is not as important as conditions insuring a constant food supply, or other environmental influences. The *Galago senegalensis moholi* and *Galago crassicaudatus* and their subspecies live in the open savanna country where there is a prolonged dry season lasting from April through October, during which their young are born. The lorises, however, live in forested tropical regions where there are no such extremes of humidity and dryness and where a restricted breeding season would have no survival value. It would be interesting to determine whether *Galago demidoffii*, a small form found in the rain forest of Equatorial Africa in the very regions in which the duikers, cited by Marshall, live, would, like them, have continuous or irregular breeding season as a result of more uniform environmental conditions.

PERIOD OF GESTATION.

As I have reported, the first period of heat, experienced by the young female under my observation, was not followed by pregnancy. The second period, however, which began five months later, proved to be a fruitful one. No peculiar conditions were noted for two months. The female then displayed increasing irritability at the attention of the male. She showed preference for the warmth of the radiator at the corner of the room and gave up jumping to high places. Her pelt became patchy between the shoulders. She looked thin and in bad condition. During the third month the female's irritation at the attentions of the male was so great that I separated them, giving each a cage. Paradoxically the female would answer the male's conversational note and seemed to enjoy talking to him from a safe distance. She showed enormous interest in food, eating very much more than usual, and seemed particularly fond of buttered bread. Since she refused cod-liver oil in milk, I smeared it on her fur, so that in licking it off she acquired an adequate dosage. During the intervals when both were liberated for exercise, the truculence of the female increased. A week before the birth of the young the female became very active in building a nest in her sleeping box. Tearing up pieces of newspaper, she carried them into the box. On the nights of April 12 and 13, 1939, she was unusually active.

BIRTH AND NUMBER OF YOUNG.

On the evening of April 14, I opened the doors of both cages to give the animals their customary exercise. The female was still in her sleeping box. On returning to the room a half hour later, I found her perched on the edge of the cage, holding in her mouth a dangling infant. All the while she was uttering a strange, protesting cry, directed at the male who had entered her cage and was watching the scene attentively. Obviously disturbed at his presence, the female jumped out of the cage onto a portiere and from there to the picture molding, her young one still clutched in her mouth. She finally made a downward leap of fully ten feet onto the bed, and from there retired to a dark corner of the room where she deposited the squeaking infant. I found a second young one clinging to the perpendicular side of the cardboard sleeping box. I cannot say just when the young were born. The pelage of one seemed still wet. The box was clean and there was no evidence of the placental membranes, which must have been eaten by the mother.

The birth of twins among galagos of this species seems to be a common occurrence, although single births do occur.

Donald Carter's field notes indicate that two young are frequently found in a nest, and Shortridge (1934, page 00) states:

"Twins seem to be of frequent occurrence. In Northern Rhodesia—Ndola—several females were found carrying twins."

"A female in a Pretoria Zoo suckled two young ones. Another female gave birth to two young in October."

Haagner (1920, page 10) states that two is the usual number at a birth. There have been other instances, however, of gravid females containing but a single foetus.

Other galagos such as *crassicaudatus* and *crassicaudatus montgari* are more likely to be carrying single foetuses (Pitman, 1934, page 159). This resembles more closely the habit of the Malagasy lemur where, as the statistics show (S.S. Flower, 1933) (*vide supra*, p. 451), among 120 births there were but three instances of the birth of twins and but one of triplets.

POST-NATAL CONDITION OF THE YOUNG.

The young, male and female, were about the size of my index finger, and almost as slender. Their eyes were partly open. The tail was curled in a loose spiral, and they were sparsely covered with a homogeneous gray pelt.

The fact that the infant galagos were able to cling to the perpendicular surface of the box, and actually to stand on all fours shortly after birth, is of interest.

The young creep about, and after the first day or two of clinging to the mother with all four feet, they may be found under her, feeding, or in the nest. While they never cling to the parent as she moves about, frequently they will climb on her back or creep between her legs when she is crouched quietly in the cage. (Pl. VI, Figs. 15, 17). When in motion, however, they are either left behind, or she picks each up in her mouth, by the neck or the back, much as a cat would her kitten, and carries them about one at a time (Pl. V, Figs. 11, 12, 13). The passive infant accommodates itself to this treatment by drawing up its legs close to the body (Pl. V, Fig. 12).

Donald Carter reports that the young *Galago s. moholi* brought in by the natives were found in the nests and never found clinging to an active parent. These observations are at variance with those recorded by Shortridge (1934) and Haagner (1920) in the cases of captive animals in the Zoological Gardens of South Africa. Shortridge states:

"The young cling to the under side of the mother and are carried about in this manner until more than half grown, the mother being much hampered in her movements, when the young become larger."

Haagner states (p. 19):

"They cling to the mother like the young of the ordinary Ringtail Lemur and South American Marmosets, and ride on her back or hang underneath her as opportunity offers."

These statements by Shortridge and Haagner imply that the mother jumps about with the young clinging to her ventral surface or her back. Careful observation of the family under discussion has never disclosed any such action. When feeding the young are on their backs on the floor of the cage and the mother remains quietly in one position. To be sure, the young do cling to the under surface of the mother by their front legs, but the hind legs are always free and protruding beyond the body of the mother. They may also be found sitting on her back (Pl. VI, Figs. 15, 16) or later on the father's back, but this is only when the animals are quiet or sleeping.

There never is any clinging action (as Haagner has suggested) such as one finds among the monkeys when the parent is active or jumping about. Shortridge's statement about the mother's being much hampered in her movements is misleading. She obviously could not move when the young were nursing, and during activity they were never attached to her in any way, unless she decided to move them by carrying them in her mouth.

In contrast with these findings, however, F. Wood-Jones⁵ and P. L. Sclater⁶ both describe the mother of the genus *Lemur* as the passive agent, the young clinging to the ventral surface of the parent, and using its own tail to help hold itself on to the parent body. The young lemur therefore is the active agent.

Hill, in 1937, described the birth of twins of the slow loris (*Nycticebus tardigradus*). He writes that the young are sturdy and that the mother placed them on the ground at the very beginning. He does not state how the mother carried them about, but implies that she does the carrying, and the young are passive.

Hill, 1937, page 388:

"She will rush toward the baby and pick it up if danger threatens, and place it down again when the risk is over. She will leave her food to do this. If the baby is marooned, it squeaks for its mother, and she will try to get to it, if she is able. If the baby is picked up for observation and replaced, she has not discarded it, but smells it, licks it clean, and allows it to go to sleep again."

Cuming, in 1838, described the habits of a *Tarsius* with her young which seems to have a striking similarity with *Galago s. moholi*. He states that the young when born have their eyes open, are covered with a good pelt of fur, are able to creep around the cage shortly after birth, and the parent carries the young around, in the mouth, just as in the case of *Galago s. moholi*.

H. Cuming, 1838, page 68:

"The young appeared to be rather weak, but a perfect resemblance to its parent; the eyes were open, and the body covered with hair; it soon gathered strength, and was constantly sucking betwixt its parents legs, and so, well-covered by its mother, that I seldom could see anything of it but its tail; on the second day it began to creep about the cage with apparent strength and even climb up to the top by the rods of which the cage was composed. Upon persons wishing to see the young one covered over by the mother, we had to disturb her, upon which the dam would take the young one in its mouth, in the same manner as a cat, and carry it about for some time; several times I saw her when not disturbed trying to get out of the cage, with the young one in her mouth as before. It continued to live and increase in size for three weeks, when unfortunately some person trod upon the tail of the old one, which was protruded through the cage, a circumstance which caused its death in a few days; the young one died a few hours after, which I put into spirits."

Le Gros Clark (1924), however, does not corroborate this observation with relation to the *Tarsius*. He states that:

"I have kept under observation several female Tarsiers and young and have never been able to confirm this" . . . (carrying of the young by mother in mouth). "The young cling to the fur of the mother's abdominal wall, grasping with both hands and feet, and are not in any way held by the mother. In this way the little animal is very often wholly concealed from view when the mother is in a resting position, clinging to a branch"—He further states that: "At birth the Tarsier has reached a comparatively advanced stage of development. The eyes are open, and though its movements are uncertain, the animal can cling to a vertical branch, and scramble about the branches in a hesitating way. When disturbed it assumes an appearance of alertness."

⁵ Wood-Jones, 1929, page 115. "Lemurs do not nurse or handle or carry their young ones, for it is not the mother that clasps the offspring, but the offspring that grips the mother."

⁶ P. L. Sclater, 1885, p. 672. "Young lemur lies nearly transversely across the belly of its mother, and, passing its long tail around her (mother) back and so on to its own neck, uses it as a prehensile organ to hold on by."

NURSING AND CARE OF THE YOUNG.

The female has two pair of mammary glands. Those of the anterior are so laterally placed that each lies practically on a line with the inner border of the arm. The inguinal pair lie closer to the median line. During the first two days the young clung to the mother by all four feet. I saw one nursing from a pectoral mamma while its body was attached transversely under the mother's arm and around onto her back. Within a few days, however, they began to stretch out on their backs in the nest, gripping the mother with their front feet, while their hind feet protruded grotesquely from under her body. Occasionally they would give a convulsive kick. At first the young were so small that the mother had no difficulty in covering all but their protruding legs with her own body. As they grew larger, however, she was obliged to lift herself more and more to accommodate them, causing her front legs to be bowed over them in a ludicrous fashion. Finally they grew so large that she could accommodate only one at a time.

During the period of nursing, which lasted three and a half months, the mother displayed an enormous interest in food. Her consumption of milk was more than twice as great as before pregnancy. And she would now even tolerate in it cod-liver oil, which perceptibly improved her pelage.

The mother kept the young clean by grooming their fur herself. At their nursing time, while they were lying on their backs, with hind legs extended, she would lick clean their genitalia.

During the period of nursing the mother's urine carried the odor of sour milk.

PARENTAL ATTITUDES.

The mother galago displayed great solicitude for her young. When they were taken out for inspection, she would go to the length of jumping close to and even brushing my arm in her agitation. When the young were put down, she promptly gripped one in her teeth by the neck and jumped to the cage, using the pendant youngster instead of her nose to lift the cage door. Having recovered one infant, she then proceeded to rescue the second, in a similar manner. A thorough licking and smelling of the young followed their return to the nest. During the first three weeks the male was kept in a separate cage except during the periods of exercise. He seemed restless and curious about the occupants of the other cage, eating relatively little and keeping his eyes glued on the activities across the room. When liberated for exercise the male invariably made his way to the cage and tried to open the then locked door. The mother, permitted to exercise with the male, seemed glad of her freedom and was willing to play to some extent. When the young were three weeks old the galagos were all placed in the same cage without ill effects.

Perhaps the separation of the parents was an unduly cautious move, but the circumstances seemed to warrant this action. For the first few weeks the mother made very soft caressing sounds to her young and they were frequently heard making small mouse-like squeaks. As the infants grew, the mother continued and the father assumed solicitous attitudes, and even up to the age of nine months they obeyed the call of the mother. During the summer months when the family occupied a screened-in porch, I often heard and watched the mother give the signal for the hour of retirement after a night's activity. Just before sunrise, she would start a soft, conversational note and the young as well as the mature male would answer her call and immediately jump to her side. Within five minutes all four would have retired into the sleeping box for the day's rest. The action of the mother indicates a greater sense of responsibility toward the young than that of the father. It is she who warns the group of any danger. When a

cat lurked on the steps leading to the porch, it was the mother who gave the alarm call ending in a shrill whistle, which warned the family and sent me on a tour of investigation. In the winter the family was moved to a large enclosure in the college greenhouse, where a shelf has been made into a sleeping box by the addition of a sliding door in which an aperture has been cut. For several minutes the family jumped and climbed and smelled about this new region. It was the mother who located the small aperture of the sleeping box and the dark quarters within. And after investigation it was she who began the conversational call which brought father and children to her side. The entire family is affectionate. The mother frequently caresses the young even though they are now more than a year old.

The maternal solicitude continued unabated and even when they were far too heavy to be carried, (up to 3 months), she still tried to lift them in her mouth and to get them back into the nest when the young were molested. After handling, also, she would lick them solicitously.

DEVELOPMENT OF THE YOUNG GALAGO.

From the beginning, as has already been stated, the young galagos could cling to surfaces and walk about on all fours. When not nursing, they were either under the mother, on her back (Pl. VI, Figs. 15, 16), or were curled up in a little nest made for them of soft tissue. In two weeks time there was a perceptible increase in size. Their pelt was heavier, but still homogeneous in color. They not only could walk about, but had begun to take small leaps of four and five inches, clumsily trying to balance on their hind legs, making efforts to climb on the struts of the cage and even to jump a few inches. Their bellies were very fat and their tails still curled somewhat. Between the second and third weeks, the young ones began to use the tongue in licking and grooming each other; they even began to lick me. When three weeks old they were approximately twice their original weights. They had minute incisor and canine teeth. They were very playful and would nip each other's tails and frolic about.

When four weeks old they could jump from the side of their cage a foot or more to its floor and back again. They could walk along a horizontal bar about a half-inch in diameter, sometimes losing their balance, but never their grip. They would now play with each other like kittens and could stand on their hind legs although their balance was still uncertain.

At six weeks the fur had become adult in appearance, the end of the hair assuming a lighter color, giving a frosted look. The chest and the lateral surfaces of the legs and arms were light orange-yellow. The longer, darker hairs standing out on the back, which are characteristic of the adult, were more conspicuous in the young ones, like a soft black fuzz. The dark markings on the face, however, were not yet as evident as those of the adult. At this time they began the moistening of the hand and foot-pads. They made great work of this operation, rubbing with energy the palm of the hand onto the sole of the foot on the same side. They scrubbed for some time, and were not completely sure of their balance.

The young galagos, which could jump from two to three feet in a horizontal position, watched with interest the action of their parents as they made vertical leaps from a window-sill and portiere to the picture molding. The first attempt at a vertical jump like those of the parents was made at the age of seven weeks when one succeeded in reaching the top of the window trim. One of the parents immediately jumped to a position beside it, and licked its fur. By the eighth week the young ones began coming down a perpendicular surface, gripping the edge in a regular adult fashion. At this time the young began making the protesting adult growl when handled. By the end of the second month, their balance was greatly improved and they could stand upright with considerable confidence.

From the age of one month the young attempted to eat solid food which was placed in the cage for the mother. By the end of the second month they were eating solid food regularly and drinking milk in considerable quantities.

Although still nursing, they were now so large that they had to be fed one at a time. By this time, the galagos had been moved into the country, and now occupied a screened-in porch, with freedom of action during the entire night. Flying moths were included in the diet of the parents. While at first the young had little interest in these flying insects, it grew as they watched the eagerness of the parents. They did not attempt to catch any themselves, but as the parents caught a moth, the young would try to take it away. The mother seems fairly willing to give up portions to her offspring. The samples were evidently pleasant, and by the twelfth week the young ones were capturing their own moths. They were not yet as quick or as dexterous as their parents, and even after succeeding in a catch, they frequently were obliged to give up their prize to a hungry parent. Picking up the discarded wings, the young would chew on the base of these for what nourishment there might remain. Cooke (1939) notes that adult *Tarsius* also chew on the base of moth wings. At three months of age they had learned to balance themselves on the rim of a jar and to dive in and extract the fluttering insect without loss of balance. By the end of the third month, the young had stopped nursing. The only evidence of infancy was the tendency to take moths from the mother, which she continued to permit them to do. They were now less rotund, and except for the soft black fuzz on their backs they looked like their parents in miniature.

SLEEP.

During sleep these animals have a tendency to crowd together, one frequently sleeping on top of another. In cold weather it is not unusual to find one adult completely hidden by a companion. They protect their eyes from the light by burying the head in the pelt of another galago. If the light is too intense, they try to crawl under any movable object for protection. At times, too, the tail is wrapped over the eye to exclude the light.

This variety does not usually sleep with the neck arched and the head tucked between the hind legs as does *Galago crassicaudatus*, although on rare occasions, when one *Galago s. moholi* has been isolated, I have seen this method employed. The large membranous ears remain somewhat folded during sleep.

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APPENDIX.

The activities outlined here occurred after the manuscript was in type.

On the evening of December 7, 1940, oestrus recurred after an interval of six months. At this time a new factor was introduced. For some weeks prior to this date the young male, now twenty months old, had given evidence of sexual maturity with the result that, at the onset of oestrus, both males were accepted by the mother. The young female, however, has not yet become sexually active.

EXPLANATION OF THE PLATES.

PLATE I.

- Fig. 1. Head of adult male enlarged 2 \times . Crescent-shaped rhinarium shown with deep median cleft. Upper lip bounded by fur. No "snarling" expression of upper lip though animal is angry. Eyes with vertical pupils. Lashes visible on upper lid of eye to right. Vibrissae evident lateral, median to and below the eye, also at side of mouth on left. Note method of grasping small stick. Thumb and index finger on one side, the three outer fingers on the other.

PLATE II.

- Fig. 2. Life size group of family of four in characteristic sleeping position, taken when young were a year old. Note corrugation of ears of animals to right and lower center.
- Fig. 3. Photograph of family on rafter under porch roof. Upper eyelids of animal third on right shown extended over bulging eyes. This galago had been perched on the rim of the flash light reflector and was looking at the bulb when it was discharged. For a short time the animal was unable to tolerate even a subdued light.

PLATE III.

- Fig. 4. Photograph of hands $\times 2$. Illustrates method of resting palm on a flat surface with the flexed digits somewhat bent to one side. Note flat nails and pads along under surfaces of digits ending in enlargements at tips. Interdigital pads shown protruding beyond palm of hand to left.
- Fig. 5. Phalanges of hand flexed for grasping food. The two distal phalanges bend over the proximal phalanx of each digit except that of thumb. Thumb opposed.
- Fig. 6. Photograph of under surfaces of hand and foot, taken from the inside of a glass door on the outside of which a galago is clinging. The index finger is shown to lie almost midway between the large space which separates the thumb and third finger. Illustrates the way in which the pads of the palm and sole flatten out when applied to a flat surface.
- Fig. 7. Photograph of under surfaces of feet taken when animal was in same position as in Fig. 6. The pads of the soles are not flattened out. Note fur-covered hinder portion of ventral surface of foot and large size of the pads of hallux, the interdigitals, thenar and hypothenar.

PLATE IV.

- Fig. 8. Photograph showing method of grasping branch by feet alone, leaving hands free for feeding.
- Fig. 9. The animal is hanging head down with hands free, grasping screen-trim by hind feet. Note the widely abducted, powerful hallux.

- Fig. 10. Adult male and female. Male standing on toes reaching for insect. Note length of foot and hind limb. Tail serves as balancing structure. Digits of the hands are somewhat flexed, which is their usual position unless grasping food or perching.

PLATE V.

- Figs. 11, 12, 13. Method of carrying young. (Fig. 11). Mother while on table-top grasps young in region of shoulder. (Fig. 12). Young lifted from table, mother poised to jump to floor; feet of young drawn up. (Fig. 13). After jump, mother depositing young on floor.

PLATE VI.

- Fig. 14. Photograph of young when two weeks old.
Figs. 15, 16, 17. Different postures when awakened from sleep. Young are about five weeks old. (Fig. 15). One baby under the mother, trying to get away from the light while the other lies on top of parent.

(Photographs reproduced as Figs. 1-10 were taken by Agnes Townsend; Figs. 11-17 enlargements of 16 mm. motion picture film taken by author).



FIG 1

A STUDY OF THE ACTIVITIES OF A PAIR OF GALAGO SENEGALENSIS MOHOLI IN CAPTIVITY,
INCLUDING THE BIRTH AND POSTNATAL DEVELOPMENT OF TWINS



FIG. 2



FIG. 3

A STUDY OF THE ACTIVITIES OF A PAIR OF *GALAGO SENEGALENSIS MOHOLI* IN CAPTIVITY,
INCLUDING THE BIRTH AND POSTNATAL DEVELOPMENT OF TWINS



FIG 4



FIG 5



FIG 6



FIG 7.

A STUDY OF THE ACTIVITIES OF A PAIR OF GALAGO SENEGALENSIS MOHOLI IN CAPTIVITY.
INCLUDING THE BIRTH AND POSTNATAL DEVELOPMENT OF TWINS

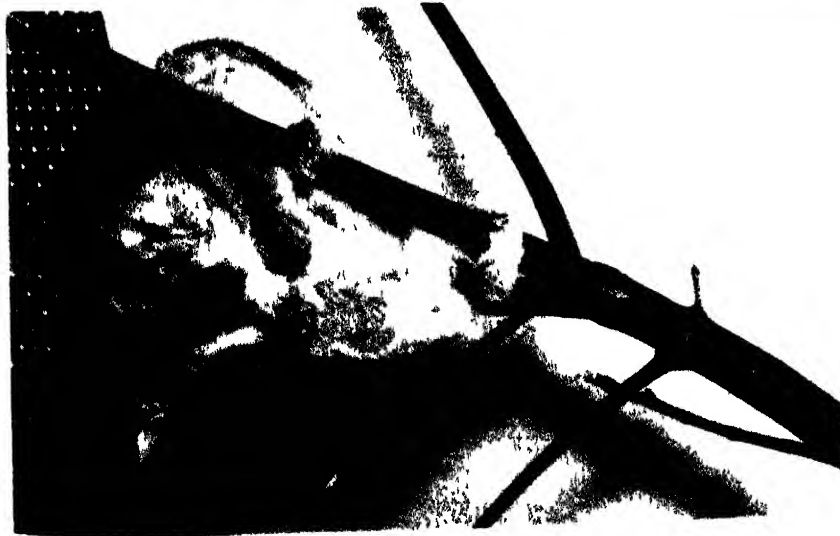


FIG 8

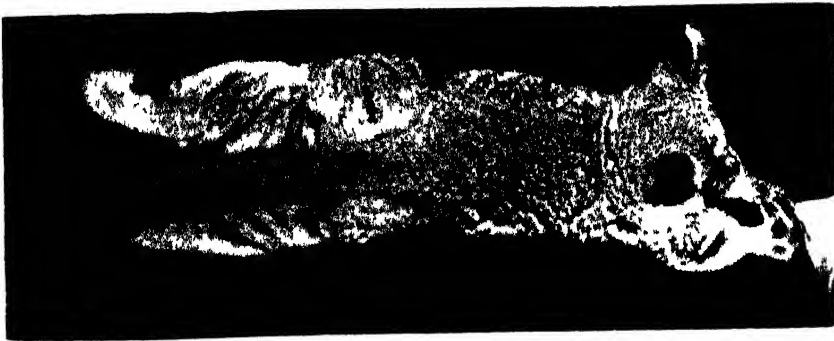


FIG 9



FIG 10

A STUDY OF THE ACTIVITIES OF A PAIR OF GALAGO SENEGALENSIS MOHOLI IN CAPTIVITY
INCLUDING THE BIRTH AND POSTNATAL DEVELOPMENT OF TWINS

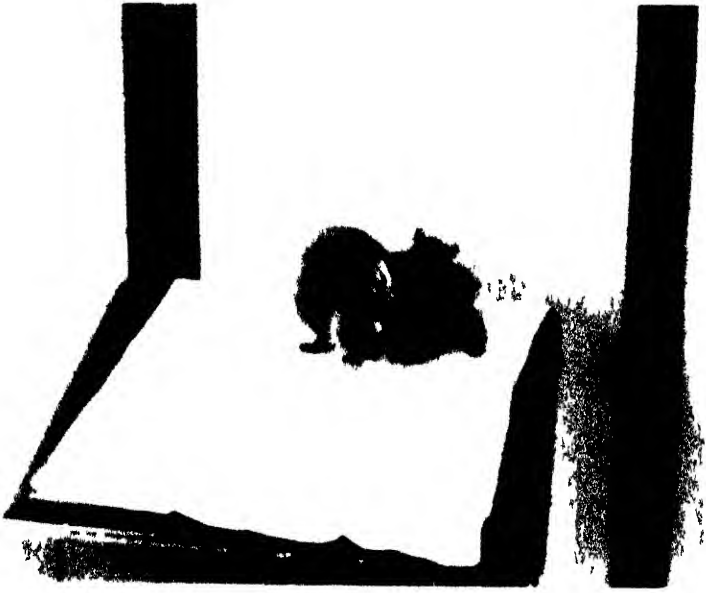


FIG 11



FIG 12



FIG 13

A STUDY OF THE ACTIVITIES OF A PAIR OF GALAGO SENEGALENSIS MOHOLI IN CAPTIVITY
INCLUDING THE BIRTH AND POSTNATAL DEVELOPMENT OF TWINS



FIG 14



FIG 15



FIG 16



FIG 17

A STUDY OF THE ACTIVITIES OF A PAIR OF *GALAGO SENEGALENSIS MOHOLI* IN CAPTIVITY,
INCLUDING THE BIRTH AND POSTNATAL DEVELOPMENT OF TWINS

28.

Diets for a Zoological Garden: Some Results During a Test Period of Five Years.¹

HERBERT L. RATCLIFFE

Advances in animal nutrition have not been applied extensively to feeding problems of zoological gardens. Yet many of the difficulties inherent in maintaining health and vigor of wild animals in this environment probably could be solved in terms of information available either for related domesticated species or for man. Presumably adequate substitutes for natural foods would permit both the exhibition of more nearly normal animals and the maintenance of breeding colonies of many species. The economic aspects of either of these results are obvious.

During the first quarter of 1935 new diets were introduced at the Philadelphia Zoological Garden. For more than ten years before this time feeding practices had not changed materially. Therefore to aid in planning new formulae, records of mammals and birds that had been autopsied from 1924 to 1934 were reviewed for definite or presumptive evidences of malnutrition. Estimates of deficiencies, obtained by this review, were substantiated by comparing the values of foods that had been available to these wild specimens with those necessary to meet the known requirements of the nearest related species, whether man or domesticated animal.

Thus far, three mixed rations have largely replaced the various combinations of foods that had been used. One of these, with supplementary fruits and vegetables, is fed to the so-called omnivorous mammals and birds. A second, with mixed timothy and clover hay, provides for the herbivorous mammals. A third is a complete diet for the greater number of the Carnivora. This system includes neither fish-eating mammals and birds, nor specialized insectivorous animals.

The degree to which requirements have been met by these diets may be estimated at the present time only by changes in the causes of death, the death-rate, the birth-rate and the development of the offspring. More exact standards have been precluded to a large extent by conditions under which this study was conducted and by the types of animals involved.

Because of the great number of species represented in this collection, changes in the causes of death may be considered more completely only when more extensive material has been accumulated. But within the five-year test period just passed, changes in death rates, birth rates and in the development of young of several animal groups seem to justify the conclusion that these food mixtures have been reasonably successful. Increasing interest in certain wild animals as experimental subjects and requests for information on feeding them, suggest that some of these observations may interest others than those immediately concerned with the management of zoological gardens.

¹ From the Penrose Research Laboratory of the Zoological Society of Philadelphia and the Department of Pathology of the University of Pennsylvania.

At the present time, discussion must be limited to the reactions of certain species of animals and birds as members of relatively large taxonomic groups rather than as individuals. These groups, as such, are believed to have had approximately equal opportunity for breeding before and since the diets were changed. Exposure to morbid influences also has been equal, except of course, as modified by diet, or, in some instances, by reduction of the number of individuals within enclosures.

OMNIVOROUS ANIMALS.

The ration designed for this rather indefinite class of mammals and birds is made up of 1 part of ground, boiled horse-meat and 9 parts of the following mixture:

Rolled oats.....	20 per cent.
Whole wheat meal.....	20 " "
Soybean oil meal.....	20 " "
Peanut oil meal.....	10 " "
Yellow corn meal.....	10 " "
Buttermilk (dry).....	5 " "
*Brewer's yeast (dry).....	5 " "
Alfalfa leaf meal (dehyd.).....	5 " "
Oyster shell flour.....	2 " "
Iodized salt.....	2 " "
**Cod-liver oil concentrate.....	1 " "

These materials are mixed in bulk and used as needed. The ration usually is prepared the day before it is fed. First the ground meat and the dry materials are mixed thoroughly, then enough meat broth (water in which the meat is boiled) is added to form a stiff mash. This is pressed into shallow pans of convenient size and refrigerated overnight at 44 to 46 degrees F. after which it has hardened sufficiently to be cut easily into pieces appropriate to the size of the animals.

Allowing for natural variation in foodstuffs the approximate composition of this ration is:

Protein	25	per cent.
Fat	5	" "
Carbohydrate	45	" "
Calcium	1	" "
Phosphorus	0.5	" "
Iodine	0.017	" " (potassium iodide in "iodized salt.")

Energy value=3 calories per gram.

A variety of materials has been included in this ration with the intention of offering a palatable food of which animals would not tire quickly. The sources of protein are varied and the mineral and vitamin content have proved adequate for growth and reproduction except in instances that will be mentioned later. Obviously the formula may be varied and other substances added or substituted for those now in use.

Subhuman Primates. Thus far, animals of the following genera have been available for observation: *Gorilla*, *Pan*, *Pongo*, *Hylobates*, *Cercopithecus*, *Erythrocebus*, *Macaca*, *Theropithecus*, *Papio*, *Mandrillus*, *Saimiri*, *Cebus*, *Lagothrix*, *Ateles* and *Lemur*. Some of these generic groups contain relatively large numbers of species of which few have been represented in

* Brewer's Blended Dried Yeast. 1938 assay claims 30 international units of vitamin B₁ and 15 Sherman units of vitamin B₂ per gram.

** Assay claims: 3000 U.S.P. units of vitamin A and 400 A.O.A.C. "chick" units of vitamin D per gram.

the collection. With the exception of rhesus monkeys (*Macaca mulatta*), these animals are kept in heated quarters during cold weather, and have little exposure to sunlight except in summer.

Prior to 1935, more than half the total diet of these animals consisted of polished rice, boiled sweet potatoes and bananas. Green foods, citrus fruits, milk and eggs, were fed in significant quantities only to anthropoid apes (Corson-White, 1922).

Since 1935, about one-half the energy intake of subhuman primates of all ages has been supplied by the mixed ration, and, with exceptions to be noted, the remainder of their diet made up of uncooked fruits and vegetables: sweet potatoes, carrots, apples, bananas, citrus fruits and green vegetables. In addition to these food stuffs, anthropoid apes also receive from 1 to 4 liters of fresh whole milk each day. The two gorillas now in the collection also are fed about 200 grams of uncooked ground horse-meat each day, and an equal quantity of boiled horse liver 3 or 4 times each week. Pregnant and lactating females and immature animals of all types are given from 0.5 to 2 liters of a milk and egg mixture (1 egg per liter) and 5 to 20 cubic centimeters of a preparation containing some 800 units of vitamin A and 250 units of vitamin D per cubic centimeter.

This diet, mixed ration and fruits and vegetables, is estimated to supply at least 10 to 12 per cent of protein, 3 to 4 per cent. of fat and 30 to 40 per cent. of carbohydrate. Because of the relatively small amounts of calcium and phosphorus contained in vegetables and fruits the percentages of these materials in the mixed ration is reduced by at least half in the total diet.

The known daily energy needs of man and lower animals permitted the assumption that food requirements per unit of body weight would vary widely with the several species of subhuman primates in the collection. In consideration of size and spontaneous activity, allowances of 100 to 200 calories per kilogram of body weight per day did not seem excessive. In actual practice, however, amount of food taken may vary widely from day to day, and dominant members of a group must always be overfed so that others will be allowed adequate amounts of food. Also, frequent feedings seem to be the most economical method of maintaining this type of animal, lessening waste and preventing overeating of any one food with subsequent loss of appetite for that or other substances. To accomplish this best, the keeper must return to the cages two or three times.

Table I is a summary of breeding and mortality records for each of the five years preceding and following the change of diet. "Total Stock" listed in the first column of the table includes all animals because records do not permit separation of potential breeding stock.

* Feeding schedule developed with the aid of Mr. M. I. Tomilin.

Monkeys	8:30 A.M.	Mixed ration (except on Sunday)
	11:30 A.M. to 12 M.	Green leafy vegetables
	2:30 P.M. to 3 P.M.	Sweet potatoes and carrots
	Offer water twice daily.	
From 4 to 16 ounces of mixed ration with 2 to 3 times these weights of vegetables will be required. Amounts are determined by size of the animals.		
Chimpanzees and Orangs		
	8:30 to 9:00 A.M.	Oranges (from October to May because of cost)
	9:00 to 9:30 A.M.	Whole milk
	11:00 to 11:30 A.M.	Green vegetables
	1:00 to 1:30 P.M.	Water
	1:30 to 2:00 P.M.	Sweet potatoes and carrots or tomatoes
	3:30 P.M.	Whole milk
	4:30 to 5:00 P.M.	Mixed ration except on Sundays when bananas are substituted
Gorillas	Feed according to the schedule for Orangs and Chimpanzees except that from 11:30 A.M. to 12 M. they receive raw ground horse-meat every day, and from 3:30 P.M. to 4 P.M., three or four times a week, each receives boiled horse liver.	

TABLE I.

Records of Births and Deaths for the Subhuman Primates at the Philadelphia Zoological Garden During Each of Five Years Before and Five Years After the Diet Was Changed.

Year	Stock		Acquisitions	Births	Deaths	Sales
	♂	♀				
1930	58	48	27	5	51	0
1931	48	39	21	2	19	0
1932	49	42	8	3	15	1
1933	48	38	9	3	11	0
1934	46	41	11	5	18	0
1935	45	40	30	6	17	15
1936	43	46	19	6	8	19
1937	34	53	13	5	7	4
1938	35	59	8	7	14	19
1939	28	48	9	12	5	0

From 1930 to 1935 the average annual birth rate was 1 for 11.6 females. This increased to 1 for 6.6 females after the diet was changed. Prior to 1935, breeding was limited to a few species of *Cercopithecus* monkeys, mainly *Macaca mulatta*, and to Orang-utans (*Pongo*) and Chimpanzees (*Pan*). All infants that survived breast feeding to the age of 12 to 16 weeks developed rickets.

With the present diet, *Macaca irus*, *M. mulatta*, *Cercocebus fuliginosus*, *Cercopithecus sabeus*, *C. grivet*, *C. mozambicus*, *Cebus fatuellus*, *Papio papio*, and *Pongo pygmaeus*, have bred about as frequently as may reasonably be expected. Except for an occasional death that could not be attributed to malnutrition, all offspring, except those of *P. papio*, the Guinea baboon, have developed normally. These baboons, of which there have been five, developed rickets, however. All of them were born in the autumn, as were many of the others, and had little exposure to sunlight. They recovered promptly with appropriate artificial feeding. Possibly the greater vitamin D requirement of the baboon will prove to be characteristic of the type and may be related to the rapid growth of the facial bones to form the typical dog-like features; for it is in this part of the body, rather than in the thorax and extremities, that abnormal bone formation first appears.

Also to be noted in Table I is the reduction in the number of males in proportion to females in the colony. Breeding possibly has been influenced by this change, but the death rate was not materially affected. Injury by cage mates has contributed little to mortality rate at any time, although occasional losses from this cause occurred throughout the period. The average yearly death rate of 12 per cent. from 1935 to 1940 is to be compared with that of 25 per cent. from 1930 to 1935.

This diet for subhuman primates is based to a considerable degree upon recognized requirements of man, especially as to vitamins and minerals. It is essentially a modification of the diets suggested for these animals by Corson-White (1931) and by Tinklepaugh (1931, 1933) but is less complex than either of these. In consideration of the known food habits of the species of subhuman primates available for study it seemed that their dietary needs might be met adequately by using a mixed ration composed of easily available foods for domesticated animals. This has given an economical and palatable mixture which, combined with accessory foods, seems to be a reasonably complete diet. An obvious fault possibly is the low fat content, but thus far there is no indication that this is an important lack.

Whatever criticisms may be offered to this system of feeding, it seemed reasonable to assume that the mixed ration with some of the supplements also would meet the requirements of many other species of mammals and

birds. In deciding upon the relative amounts of mixed food, vegetables and fruits for these animals, preferences as well as presumed needs, as indicated by experimental studies of diet, field studies of food habits and the structure of the intestinal tract, have served as guides.

Other Mammals. The mixed ration that has been described constitutes from 50 to 60 per cent. of the diet of rodents of the following genera: *Glaucomys*, *Sciurus*, *Citellus*, *Hystrix*, *Erethizon*, *Dasyprocta* and *Neotoma*. Supplementary foods are apples, carrots, sweet potatoes and green vegetables. This diet, the mixed ration and vegetables, also forms from 60 to 70 per cent. of the intake of the bears (Ursidae) and raccoons, coatis and kinkajous (Procyonidae). Horse-meat and fish supply the remainder of their intake. The present quarters for these animals do not favor breeding, but as judged by appearance, activity, growth of fur and postmortem examinations, the diet seems adequate for growth and maintenance.

Birds. A large number of species of so-called seed- and insect-eating birds, Passeriformes, many of the parrots, Psittaciformes, all Columbigiformes, Galliformes, and Anseriformes, are fed one diet, the chief element being the mixed ration that was developed for the apes and monkeys. This food makes up about 70 per cent. of their intake. Supplementing it are green vegetables, sprouted grains and fruits. In view of the known food habits of many species of Passeriformes, the mixed ration is probably too low in fat content to be completely satisfactory, and it has proved to be unsuited for unfeathered young of local species of this order. Further investigation is necessary to determine whether or not a special diet for the adults of this order is economically justified. During the present test period these birds have shown noteworthy improvement in plumage colors, and lessened morbidity and mortality.

Breeding as a measure of the adequacy of the diet must, however, be limited to birds of the families Phasianidae and Anatidae, for few others are exhibited under conditions favorable to this activity. Prior to 1935, about 70 per cent. of the intake of these two families consisted of a mixture of equal parts of cracked corn and wheat screenings, supplemented by green vegetables. Crushed limestone and oyster-shell were supplied ad libitum to the pheasants.

Phasianidae. The pheasants, junglefowl and larger varieties of quail are exhibited in pens that provide from 150 to 200 square feet of floor space. Small types of quail have less space while wild turkeys are exhibited in a much larger pen, and peafowl are at liberty on the grounds. Visitors may pass within a few feet of all enclosures. From two to seven pheasants of one species, with one adult male to the group, occupy each pen. Junglefowl, turkeys and quail are kept in small flocks in which there may be more than one male.

From 1930 to 1935, breeding in this group was limited chiefly to silver pheasants (*Gennaëus nycthemerus*) but occasional young were produced also by Swinhoe's pheasant (*Gennaëus swinhoii*), junglefowl (*Gallus gallus*), the common peafowl (*Pavo cristatus*) and stubble quail (*Coturnix coturnix*).

Since the present diet was offered, five species of pheasants have produced fertile eggs regularly, but none has had greater than 15 per cent. fertility. Compared to this is the fertility rate of more than 50 per cent. for wild turkeys and three species of quail. But in spite of the relatively unfavorable conditions under which these birds live, the number of young produced by this group from 1935 to 1940 was four times greater, in proportion to the breeding stock, than from 1930 to 1935, and the annual death rate fell from 38 to 24 per cent.

Anatidae. Many of the members of this family are exhibited in one body on an artificial pond. Others are kept in smaller enclosures along a

stream. The mute swan, (*Cygnus olor*), is the only species provided with a separate space where the pair may nest. In all locations visitors may approach within a short distance of the birds.

From 1930 to 1935, breeding was limited to Canada geese, (*Branta canadensis*) and mallard ducks, (*Anas platyrhynchos*), which hatched an average of twelve young per year. With the present diet these continue to breed and, in addition, mute swans, (*Cygnus olor*), and upland geese (*Choenephaga magellanica*) have produced young regularly, and blue geese (*Chen cocrulescens*) and Egyptian geese (*Alopochen aegyptiacus*) have occasionally nested. From 1935 to 1940, an average of 43 young were hatched each year. Young birds of both the family Anatidae and Phasianidae are fed the mixed ration with about 10 per cent. of finely chopped green vegetables. Growth has been entirely satisfactory and loss negligible. This diet for Phasianidae and Anatidae corresponds in all essentials to that developed by Callenbach, Murphy & Hiller (1932) for ring-necked pheasants. More recent experimental studies of the nutritional requirements of chickens, pheasants, turkeys, ducks and geese, (Barnum, 1935), (Baird & Green, 1935), (Bethke, Record & Kennard, 1936), (Norris, Elmore, Ringrose & Bump, 1936), (Milby & Henderson, 1937), show that the food supplies all necessary elements in adequate quantities, especially those essential to high fertility and good "hatchability."

Breeding of both Phasianidae and Anatidae probably has been limited more by small enclosures, crowding by other species and by disturbances of visitors than by any other factors. Pheasants should have larger pens, and geese and swans probably should be separated in pairs for the best results.

HERBIVOROUS ANIMALS.

The composite ration used for herbivorous animals contains beet pulp, chopped vegetables and a portion of the following dry mixture:

Brewer's grains (Dry).....	400 lbs.
Yellow cornmeal.....	200 lbs.
Crushed oats.....	200 lbs.
Soybean oil meal.....	200 lbs.
Alfalfa meal (Dehyd.).....	100 lbs.
*Brewer's yeast (Dry).....	40 lbs.
Oyster-shell flour.....	40 lbs.
*Iodized salt.....	10 lbs.
*Codliver oil concentrate.....	5 lbs.

This mixture also is prepared in bulk for use as needed. The ration is made up in the late morning and fed in the early afternoon. The beet pulp is wet with an approximately equal weight of water and soaked for 1 to 2 hours. An amount of the dry mixture equal to the dry weight of the beet pulp, and chopped cabbage or carrots in an amount about equal to 10 per cent. of the total dry weight, are added and the whole well mixed. This forms from 60 to 70 per cent. of the diet of the herbivorous animals. The remainder is obtained from mixed timothy and clover hay. With different species of herbivorous animals the feeding allowances of the mixed ration vary between 10 and 40 grams per kilogram of body weight, or 1 to 4 pounds of the completed mixture per 100 pounds of body weight.

The approximate composition of the completed ration is:

Protein	15	per cent.
Digestible protein.....	11.5	" "
Total digestible nutrients.....	70	" "
Calcium	1.16	" "
Phosphorus	0.25	" "

* See formula for omnivorous animals.

This mixture is a modification of rations that have been developed for cattle and sheep (Morrison, 1939). In view of the type of hay available, the protein content is lower than that usually recommended. But the problem here is simply one of maintaining breeding stock in good condition. Neither milk production nor rapid gains in weight are considerations. Beet pulp is used as palatable diluent because concentrates are not tolerated well by deer in captivity. Vegetables are included also for palatability. The cost of the mixture compares favorably with others that provide equal amounts of digestible nutrients with smaller numbers of constituents.

Artiodactyla. The majority of herbivorous animals that have been available for study are included in the families Cervidae, Bovidae and Camelidae of the order Artiodactyla. Some species of cervines and bovines always have bred in the garden. Hence consideration will be given mainly to these groups.

All of the deer, Cervidae, except delicate tropical species such as the barking deer, *Muntiacus muntjak*, all of the Camelidae and the hardier Bovidae, are kept in open paddocks throughout the year. These are provided with tight shelters. African antelopes, Bovidae, live in heated quarters during the cold weather, but have access to outdoor enclosures during the warmer months. Natural pasturage is scanty or absent in all pens.

Prior to 1935, approximately half the diet of these ruminants was made up of mixed grains (equal parts by volume of cracked corn, crushed oats and wheat bran) and the remainder of mixed timothy and clover hay. Rock salt was the only mineral supplement. African antelopes received small amounts of fresh vegetables twice weekly.

TABLE II.

Records of Births and Deaths for Three Families of Artiodactyla (Bovidae, Cervidae and Camelidae) at the Philadelphia Zoological Garden During Each of Five Years Before and Five Years After the Diet Was Changed.

Year	Stock		Acquisitions	Births	Deaths	Sales
	♂	♀				
1930	70	48	1	20	14	6
1931	77	42	3	19	15	4
1932	74	48	2	17	24	2
1933	67	48	0	21	12	8
1934	59	57	15	16	24	10
1935	60	53	6	20	28	14
1936	53	44	12	14	18	9
1937	53	43	15	16	10	16
1938	54	47	0	18	13	24
1939	41	41	6	20	7	10

Neither the birth rate nor the death rate of these animals has changed materially since the present diet was offered. From 1930 to 1935, the average annual birth rate was 1 for 2.6 females and from 1935 to 1940, 1 for 2.3 females. The average annual death rate was approximately 15 per cent. throughout the period, but would have fallen to 12 per cent. after the change of diet, except for the sacrifice of 16 animals as excess or as unfit specimens.

From these observations it appears that the present diet offers little advantage, but the response of the ruminants is not well expressed by these data. Certain species of Cervidae and Bovidae seemed to be able to live and reproduce fairly well on the former diet. Examples of these are the Barbary sheep, *Ammotragus lervia*, Sika deer, *Sika nippon*, and possibly the Central American deer, *Odocoileus virginianus nemoralis*. On the other hand, American bison, *Bison bison*, elk, *Alces alces*, fallow deer, *Dama dama*, red deer, *Cervus elaphus*, Axis deer, *Axis axis*, and white-tailed deer, *Odocoileus*

leucurus, also reproduced but young matured slowly, rarely attaining the stature of wild-bred specimens. Many offspring of all species died shortly after birth, either because of lack of vigor or failure of the mother to lactate; and adult elk and white-tailed deer commonly developed progressive paralysis of the posterior extremities, due possibly to vitamin A deficiency.

The present diet seems adequate for maintenance of all species of Artiodactyla with which it has been tested. White-tailed deer have not developed paralysis of the posterior extremities during the five-year test period. Elk were not available for part of the time. Occasionally, newborn young, especially of hog deer, *Hyelaphus porcinus*, are lost shortly after birth, but in general, offspring mature normally. As one example, two generations of barking deer, *Muntiacus muntjak*, have bred while confined entirely within doors.

More recent studies of the nutritional requirements of domesticated ruminants, (Thurston, Eckles & Palmer, 1926), (Bechdel and co-workers, 1928), (McElroy & Gross, 1939), (Winegar, Pearson & Schmidt, 1940), indicate that the present diet for wild ruminants may be unnecessarily complex. Possibly it is, but the use of such a mixed ration seemed to be justified by the conditions under which the animals are exhibited, and by the fact that it is fed to non-ruminant herbivores such as the elephant, rhinoceros, hippopotamus, tapir, kangaroo and hyrax.

CARNIVOROUS ANIMALS.

Mammals and birds of this dietary group receive a ration which contains raw, ground horse-meat (approximately 20 per cent. glandular organs) 60 per cent., ground green vegetables, 10 per cent., and 30 per cent. of the following mixture:

Soybean oil meal.....	30 per cent.
Peanut oil meal.....	25 " "
Buttermilk (Dry)	25 " "
Oyster-shell flour	6 " "
Alfalfa leaf meal (Dehyd.)	4 " "
*Brewer's yeast (Dry).....	4 " "
*Cod-liver oil concentrate.....	4 " "
*Iodized salt	2 " "

This is fed to animals of the families Canidae, Mustellidae, Viverridae, and Didelphiidae, and to birds of the orders Strigiformes and Accipitriformes. For these animals daily feeding allowances are 75 to 100 grams per kilogram of body weight, or 1 to 4 ounces per pound. It also forms part of the diet of other mammals and birds, but it has not been a successful diet for adult wild Felidae. On this diet, "husky dogs," foxes, wolves, skunks and opossums have bred successfully and offspring have matured without obvious defects. Judged by breeding, development of young and growth of fur, the ration seems to be adequate for these animals.

The hawks and owls, Accipitriformes and Strigiformes, have not had opportunity for breeding but the drop in mortality rate has been so pronounced as to warrant mention. From 1930 to 1935, the stock of Accipitriformes averaged 39.6 birds each year of which about 30 per cent. died. With almost the same average stock, 40.8 birds, from 1935 to 1940, the annual death rate has dropped to less than 10 per cent. The average number of Strigiformes exhibited from 1930 to 1935 was 19.8 birds of which 59 per cent. died each year. From 1935 to 1940 an average stock of 32.2 birds also lost less than 10 per cent. Prior to 1935 these birds had been fed only horse-meat. The chief causes of death were either non-specific inflammatory disease of the intestinal tract or simply failure of appetite. These conditions are no longer factors in mortality.

* See diet for omnivorous animals.

This diet for carnivores is one of many combinations that have been tested. Early in the work, 30 per cent. of the dry mixture for omnivores was used instead of the present dry material with the result that much of the grain-meals were undigested and stools were soft. This is in keeping with the observations of Hodson & Maynard (1938) on mink. In its essentials the present diet corresponds to the suggestions of Kellogg (1939).

On the whole this work has been an attempt to adapt available standards of nutrition to the needs of a zoological garden. The aim has been to provide acceptable, adequate and economical diets. Little training is necessary to induce the animals to take the foods, and costs of feeding have been reduced approximately 20 per cent. Whether or not the diets are completely adequate, in that continued breeding in captivity will be possible, remains to be determined. In all probability, the mixed rations that are being used could be further simplified without loss. The inclusion of iodized salt in all mixtures may be questioned, but its need seemed indicated by the frequent occurrence of hyperplasia of the thyroid in both mammals and birds that were examined prior to 1935.

It must be emphasized that a five-year test period is a relatively short time in which to evaluate reactions to these diets. This interval is only part of the normal life-span of all except the more short-lived specimens. The responses of the second and third generations must be awaited.

In planning the formulae efforts were directed to simplifying mixtures, using easily weighed amounts or standard bulk quantities as much as possible. Also, in actual practice food allowances are not arranged on a grams per kilogram of body weight per day basis. Instead, easily understood measures of the prepared foods are employed so that neither the keepers nor the workmen who prepare the foods are compelled to do more than follow a simple routine.

SUMMARY.

A rather elastic classification of mammals and birds according to known food habits and the general structure of their alimentary tracts, permits the subdivision of the greater number of species that are exhibited in zoological gardens into three general groups. Three diets, the make-up of which was determined by the known requirements of related species, whether man or domesticated animal, by the preferences of the wild specimens, and by practical considerations, have been used for five years. Response to these diets, as judged by death rates, birth rates and development of young, indicate that advances in human and animal nutrition may be successfully applied to the feeding problems of zoological gardens.

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29.

The Biology of the Smoky Shrew (*Sorex fumeus fumeus* Miller)¹

W. J. HAMILTON JR.

Zoology Department, Cornell University
Ithaca, New York.

(Plates I-IV; Text-figure 1).

The long-tailed shrews (*Sorex*) are cosmopolitan creatures, representatives of the genus occurring throughout most of North America, Europe and Asia. They reach their greatest numbers in temperate and sub-arctic lands, occupying a variety of habitats but seeming to prefer damp situations. Often these shrews are the most abundant mammalian representatives of extensive habitats, but their habits are little known. They have been religiously catalogued by the systematist, but as with most species, we know little more than their names, colors and measurements. This surprising dearth of information on such widespread and ubiquitous creatures is not surprising, for their diminutive size and retiring habits make them unworthy subjects for the attention of most naturalists. Nevertheless, these little mammals hold a peculiar fascination for some, for almost any planned study on these creatures will provide new information on their habits. The long-tailed shrews, if for no other reason than their very abundance, must play an important role in the habitat which they occupy.

The rate of growth, food habits, reproduction and behavior of *Sorex* has been little studied in North America. The best accounts, which are all too fragmentary, have been written by European students, the subject of their attentions being largely confined to the common shrew (*Sorex araneus*).

In 1927 I commenced a study of the small forest mammals of New York. Special efforts were made to secure life history data on the long-tailed shrews (*Sorex*). As time and opportunity have permitted, attention has been directed to solving the life history of the smoky shrew (*Sorex fumeus*). My repeated efforts to secure live gravid females, so that the young might be raised and described, have failed, but considerable data have been accumulated during the past ten years of study. Most of my studies have been made about Ithaca, in central western New York. The summers of 1937 and 1938 were spent on the Edmund Niles Huyck Preserve at Rensselaerville, Albany County, in eastern New York where large numbers of shrews were collected and population studies completed. Five hundred and sixteen shrews have been collected during the course of the study, and these have provided sufficient fresh material for rather complete studies on the various phases of the life of the smoky shrew.

Specimens were secured in small snap-back mouse traps baited with walnut meat, while a few shrews were captured alive in Sherman metal boxtraps.

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DESCRIPTION.

The smoky shrew is a relatively large *Sorex*, heavier and more powerfully built but with a shorter tail, than *Sorex dispar* which occupies part of its range. It is much larger than the common masked shrew, *Sorex cinereus cinereus*, which is occasionally found in the same runways.

The winter pelage differs decidedly from that of the summer pelage. In winter the upperparts are deep mouse gray or slaty; the underparts are very much lighter, almost silvery. Some specimens have a buffy suffusion in the post-abdominal region. In summer pelage the upperparts are pale grizzled brown, the hair tips of the underpart being paler and gray at the base. The tail at all seasons is bicolored, straw yellow below and brown above. I have seen no albinistic specimens but old specimens occasionally have the hair tipped with white, or there may be a small patch of white fur on the thigh.

Summer specimens may be confused with *Sorex cinereus* (Townsend, 1935), but their greater size and darker color serve to distinguish them from their lesser kin.

Measurements. Three conventional measurements are made of mammals when they are caught and before they are made into scientific specimens, viz., total length (nose to end of last tail vertebrae); tail (base of tail to end of last tail vertebrae); hind foot (heel to end of longest claw). These measurements, unfortunately, vary with the collector and his methods, the condition of the specimen whether fresh, bloated, in rigor mortis, etc., and are largely a matter of personal equation. All the measurements listed below were made by myself, from freshly caught specimens taken in New York State.

Adult males. Twenty-six specimens average: total length, 116.5 mm.; tail, 41 mm.; hind foot, 13 mm.

Adult females. Twenty-two specimens average: total length, 116.3 mm.; tail, 43 mm.; hind foot, 12.6 mm.

Immature males. Seventeen specimens measure: total length, 113.5 mm.; tail, 41.4 mm.; hind foot, 12.7 mm.

Immature females. Fourteen individuals measure: total length, 113.1 mm.; tail, 41.2 mm.; hind foot, 12 mm.

Thus the measurements of 48 adults of both sexes average: total length, 116.4 mm.; tail, 41.9 mm.; hind foot, 12.8 mm. Thirty-one immature specimens average: total length, 112.8 mm.; tail, 41.3 mm.; hind foot 12.6 mm.

It is thus evident that the conventional external measurements provide little data on relative age, at least with this species. It is my belief that this is true of many small mammals. This belief is based on measurements of many hundreds of small mammals of various species in northeastern United States. Weights, external appearance (pelage, hairy tail tufts or bare tail tips, scarring of tail and feet) and above all, weight give a good index to the age of this shrew, and combined, are sufficient in themselves to give a ready clue to the approximate age of the animal. Tooth color and wear are infallible, and should always be resorted to in order to determine the age of the individual.

Weight. The smoky shrew has a variable weight, depending upon the amount of food it has recently ingested and also on its condition. Sufficient numbers, however, taken throughout the year, show a remarkable difference between the immature and mature animals, and the two may readily be separated on this factor alone.

Recently weaned shrews, about one month old, weigh 4 grams. They gain weight slowly and throughout the first 7 to 10 months of their lives weigh from 4 to 6.8 grams. Immature individuals of both sexes collected from June to November weigh from 5.5 grams to 6.8 grams, the average of 97 specimens of both sexes being 6.19 grams. There is no sexual variation in the weight of immature shrews.

During March, the shrew population (those which have been born the previous year) gain weight rapidly and continue to become heavier throughout the spring and summer until they die. Twenty-nine adult males collected from March to August average 8.94 grams, the extremes ranging from 6.4 grams to 11 grams. Twenty-four females collected during the same period average 7.44 grams, the extremes for these, with embryos removed in gravid individuals, being 6.7 grams to 10 grams. It is very unusual to take these adult shrews after August, and it will be shown later that they die of old age at this season.

Molt. It has already been shown that the summer pelage varies markedly from that of the winter, but the change by no means occurs at the same time each year, and it may occupy several months in any one region.

Jackson (1928) states that in the southern part of the range of *Sorex fumeus* the spring molt may begin as early as the middle of April, though most specimens at that time are still in full winter pelage. He records individuals showing molt from April 19 in the south to July 18 in the north. Jackson observed that the fall molt occupies the period during October and November, depending in part upon the latitude.

In New York it is usual to find these shrews in full winter pelage from late September until early May, although the majority of museum specimens are in summer pelage. This merely indicates that collectors are most active during the summer months. The progress of the molt is a rather insidious affair, sometimes well marked and again the hairs being shed generally over the entire body so that little demarcation can be seen between the gray pelage of winter and the brown hairs of summer. The earliest record of molt is seen in an April 22 specimen, which has a large patch of summer fur on the belly and chin.

Usually by mid-May the summer pelage has been obtained, although it may be long delayed. An adult male taken on May 6, 1938 has a few hairs of the winter pelage remaining irregularly over the back, the inguinal region and particularly the rump. On June 21, 1936, I collected an adult female which had attained the complete summer pelage except for a small patch of winter fur about the base of the tail.

The summer pelage is retained until late September or early October. Three immature shrews collected in the last week of September, 1935 and 1936, have a few patches of summer fur, usually about the head and base of the tail. Fifty-seven immature shrews collected from September 27 to October 9 were all in winter pelage except one, which had a few hairs of the summer pelage about the ears. Males tend to molt earlier in the spring and fall than females. Breeding is well under way and the first litter produced before the females have completely shed their winter coat. This is contrary to the findings of Green (1930) who trapped a gravid female on April 18, 1928, at Ricketts, Pennsylvania, in which the molt was beginning on the abdomen.

A smoky shrew is seldom collected which shows any sharp demarcation between the winter and summer pelage. The molt appears to commence on the belly, and extends over the shoulders and middle of the back, the old fur persisting longest about the ears and rump.

Inasmuch as shrews in any given locality exhibit all stages of molt over a rather long period, particularly during the spring, it might be assumed that the change of fur in the individual occupies several weeks. Wilcke (1938) observed that a captive *Sorex araneus* shed its long gray shaggy winter coat during the first two days of captivity, assuming the dark shiny summer coat in rapid time.

On May 6, 1938, I collected a large male at Ithaca, New York, which showed a prominent molt over the back and rump. Long winter hairs stood out irregularly from the new short brown fur of summer. During the two days this animal remained alive, all the winter fur was lost.

HABITAT.

The smoky shrew is a northern species, reaching its abundance in the cool forested regions of Pennsylvania, New York and New England. In the beech-hemlock-striped maple woods with a ground cover of loose leaf mold and black friable soil, it is often found in considerable numbers, and, unlike its congener, *Sorex cinereus*, appears to be largely restricted to such a habitat. In New York it is often abundant in birch-hemlock woods, but is only poorly represented in the thin-soiled, rocky, dry, maple woods. While the shrew perhaps favors damp woods, and the vicinity of streams, it is often taken in areas far removed from water. This species seems particularly fond of the moss-covered boulders which lie along the wooded south slopes of valleys, where the sun does not penetrate far in the summer.

In the deep leaf mold of northern forests, one can often push a finger through the surface layer to find a cavernous void beneath the inch or two of soil which covers so completely the world beneath. By tearing away this superficial layer, the tortuous galleries and broad runways of many small forest mammals are exposed. It is in this retreat, made by the larger *Blarina*, red-backed mice, hairy-tailed moles, and kindred forms, that the smaller *Sorex* are often found in profusion, a highway of mammal travel scarcely visualized by the inexperienced observer. During the hot days of August, 1938, I made several records of temperature in these retreats. In the open woods and the borders, my thermometer read 89° F. Within the woods, where little direct sun penetrated, the temperature was 81° F. In the covered galleries of the small mammals, 6 to 10 inches below the level of the forest floor, the temperature read 69° F. Conversely, in the winter, when the forest floor was free of snow, the galleries of these animals, hidden below the forest litter, had a temperature ranging from 20° F. to 31° F. while the exposed forest floor had a temperature of 8° F.

The clumps of yew (*Taxus canadensis*) which grow from the deep leaf mold are favorite retreats for these small shrews and many have been captured in such places. The runways of moles, the tunnels canopied by rotting logs and the leaf-filled depressions which obscure so well the labyrinth of tunnels, all yield their *Sorex*.

The smoky shrew population is by no means evenly distributed throughout the forest. While there is no evidence of a communal or gregarious nature, they prefer certain localities to others and here they may often be found in some numbers. A typical habitat is shown in Plate I, Fig. 1.

ACTIVITY.

In general, shrews are active at all hours, trapping records to date not indicating that these animals have any particular time in which to feed or move about. The three common shrews of eastern United States, *Blarina brevicauda*, *Sorex fumeus* and *S. cinereus*, are active at all hours of the day and night. It appears possible that the presence or absence of suitable cover may limit their movements to certain periods, but my trapping records do not indicate this. By far the greater number have been taken at night, but this is accounted for by the collecting methods employed. In the course of the investigation, traps have been generally set in the afternoon and not attended until the following morning, so that no positive record has been obtained for the majority of specimens collected.

In order to determine at what hour catches were made, large numbers of traps were set at various times of the year and visited at 6-hour intervals. The results appear in Table I.

TABLE I.

Activity of *Sorex fumeus* as determined by time of catch.

	6 AM-12M.	12M-6 PM.	6 PM-12M.	12M-6 AM.
June 12-14, 1932				
150 traps set				
5-6:30 AM June 12	2	4	3	2
April 14-15, 1939				
130 traps set				
1-2:30 PM April 14	3	2	5	3
June 24-27, 1937				
200 traps set				
6 PM June 24	5	3	8	6
Oct. 6-7, 1938				
140 traps set				
3 PM Oct. 3	3	5	1	5

From the table above it can be seen that 27 shrews were taken from 6 A.M. to 6 P.M. while 33 shrews were trapped from 6 P.M. to 6 A.M. Although the number is admittedly small, it shows that these shrews are active at all hours. Inasmuch as these shrews live in the deep leaf mold and forest litter, they are not particularly susceptible to predation at any particular time. Their diminutive eyes probably hardly distinguish light from darkness.

ASSOCIATES.

The forest floor which serves these little shrews, provides a home for many other species. Within the same habitat many other small mammals are to be found, perhaps competing with these mammal sprites for nest sites and food. These associates vary in their numbers both from year to year and in the various habitats which one selects to study. The relative population of these to other small species may best be illustrated by noting all mammals taken on a trap line over a unit of time in similar habitat. The following examples will serve.

Maple-beech-hemlock woods, good leaf mold. Ithaca New York, June 28-29, 1939. Three hundred trap nights. *Sorex fumeus*, 9; *Blarina brevicauda*, 27; *Napaeozapus insignis*, 10; *Peromyscus leucopus noveboracensis*, 9. *Sorex fumeus* represents 16.4% of catch.

Beech-hemlock woods with deep leaf mold. Rensselaerville, New York. August 6-14, 1938. Seven hundred and fifty trap nights. *Sorex fumeus*, 18; *Blarina brevicauda*, 60; *Peromyscus* (principally *P. leucopus noveboracensis*), 66; *Synaptomys cooperi*, 6; *Zapus hudsonius*, 2; *Microtus pennsylvanicus*, 1. *Sorex fumeus* represents 11.8% of the catch.

Beech-hemlock woods with deep leaf mold. Ithaca, New York. Oct. 4-7, 1939. 800 trap nights. *Sorex fumeus*, 27; *Blarina brevicauda*, 24; *Peromyscus leucopus noveboracensis*, 26; *Clethrionomys gapperi*, 7; *Pitymys pine-torum scalopsoides*, 2; *Microtus pennsylvanicus*, 2; *Parascalops*, 1. *Sorex fumeus* represents 20.2% of the catch.

In the records above, it is seen that *Sorex fumeus* comprises 11.8 to 20.2% of the small mammal population in ideal shrew habitat for certain regions in New York. If these totals be averaged, it is found that, in the three areas discussed, *Sorex fumeus* comprises 18.3% of the small mammal population. In the northern part of the state, as the Adirondack region, and much of northern New England, certain species become more abundant, such as *Clethrionomys* and *Sorex cinereus*, and the *fumeus* population in these regions would comprise a smaller percentage of the catch.

BURROWS AND NESTS.

The weak feet of these small shrews make digging a difficult procedure and as a consequence they utilize and occupy burrows made by larger mammals. Deep in the leaf mold are prominent subterranean galleries, some the diameter of a baseball, and others whose bore scarcely exceeds the diameter of a penny. In these burrows, from an inch to nearly a foot below the leaves and humus ceiling, a host of small mammals move, feed, breed and die. These burrows are made chiefly by the powerful hairy-tailed mole, the short-tailed shrews and certain small rodents, notably the red-back mice, jumping mice and lemming mice. Chipmunks often tunnel for some distance below the soil, and the loose texture of the rotting logs and stumps make progress easy beneath these decaying objects. The tiny *Sorex* utilize these burrows, and are often caught in such places. They occasionally occupy the punky moss-covered logs which lie half hidden in the trash and rotted leaf mold of the forest.

As evidence that little burrowing is done by these diminutive creatures, I placed smoky shrews in sizeable aquaria partly filled with friable loam pressed to a consistency found in the normal habitat of these animals. Little effort was made to dig, and when the animals did try to displace dirt with their fore paws, the efforts were weak and ineffective. It seems probable that they make no burrows but utilize entirely the runways of other species.

The nests are placed at various places in these tunnels, a favorite site being beneath a stump or rotten log. I have found one nest composed almost entirely of the hair of a cottontail rabbit, situated beneath a stump from which a shrew ran when the nest was exposed. Other nests which I have examined have been made of shredded leaves, usually situated from 4 to 9 inches below the surface. These nests are roughly spherical in shape and approximate a baseball in size. They are more compact and somewhat smaller than the bulkier nests of *Blarina*. One nest which I presume had been made by a smoky shrew (a specimen was trapped in a runway leading from the nest) was situated in a punky log which crumbled apart easily. The nest was placed at one end of the log near its base and communicated with several burrows leading into the soil beneath. Another was found at the bottom of a large mass of rotten logs which had been piled by a woodcutter, and allowed to disintegrate. This nest was placed directly on the ground, between two logs which formed part of the foundation of the pile.

None of the nests contained remains of food, but piles of scats were usually found within a few inches of the nest. Captive shrews are certainly sanitary creatures, often reserving a corner of the aquaria farthest removed from the nest in which to deposit their feces. All the nests which I have examined have been free of parasites.

VOICE.

The long-tailed shrews utter diverse little notes, all with probably some meaning. When alarmed, or approached by a larger mouse or shrew, the smoky shrew utters a high pitched grating note, not unlike that of the smaller bats. If greatly disturbed, it will throw itself on its back, and with spread and waving legs, repeatedly utter these squeaking staccato notes. When foraging for food these little shrews utter an almost indiscernible twitter. I have twice seen these little forest mammals rooting through the leaf mold or appearing on the forest litter about rotted logs, the twitching nose and vibrissae held aloft, and this faint, almost inaudible twittering was kept up continually.

SENSES.

In spite of the diminutive eye (Plate I, Fig. 2) sight appears to be of some importance. In very subdued light where captives were housed, the shrews experienced little difficulty in avoiding obstacles and actually turned from their trails to explore new objects which were placed in the pens while the animals were exercising. In the thick carpet of leaves and the dark tunnels beneath the forest litter, there is little need of good eyesight and it is probable that these organs are degenerating.

The sense of smell does not appear to be particularly well developed. Little opportunity was had to test this sense, but when odorous food was placed in the boxes of hungry shrews, the animals often appeared to experience difficulty in locating the food items. Indeed, on several occasions they came within a few inches of small pieces of liverwurst, which were shallowly buried, but did not find the food until they had hunted for some time.

Hearing is reasonably acute. Gentle squeaking will alarm the shrews, while loud and prolonged clapping of the hands will cause the shrews no disturbance. Blossom (1932) refers to the apparent immunity of *Sorex cinereus* to loud sounds. Sleep is often so sound that snapping the fingers or loud whistling fails to disturb the shrews immediately.

The tactile sense appears to be well developed, and the long facial vibrissae may well enable the shrew to intercept disturbances which the other senses fail to detect. Indeed, there is some reason to believe this, else why do these little creatures forever hold their long cartilaginous snouts in the air, the mobile tip and associated vibrissae moving so rapidly that it is all the observer can manage to follow these extraordinarily rapid motions?

FOOD.

The smoky shrew is admirably adapted for gleaning the forest floor. Its long snout, with stout inner cartilaginous support, enables it to push through the leaf mold and loose litter, and its strong hooked and protruding incisors act as efficient tweezers to gather the minute life which swarms in this habitat. Elsewhere (Hamilton, 1930) I have reported on the stomach contents of 31 *S. fumeus* which were taken from February to December. All of these contained insect remains, these being, in the order of their abundance, undetermined larvae, Coleoptera, Diptera and Hymenoptera. In addition, centipedes, sowbugs, earthworms, salamanders and vegetable matter were found.

I now have the analyses of 168 stomachs to report. These were taken in New York during every month, but the greater majority were secured in the spring and the fall. Specimens taken while a deep layer of snow covered the ground contained fragmentary remains of insects, principally small golden pupal cases and fragments of beetles which were presumably dormant. One contained what appeared to be the meat and skin of a beechnut. A dozen shrews secured in March while the ground was well frozen contained quantities of insect fragments, including dipterous remains and the legs of centipedes. During May the shrews feed chiefly upon insects, particularly beetles and their larvae, and eat a few spiders. One shrew had the toes and flesh of a small salamander, while another had parts of a snail, probably *Polygyra*. Still another had eaten several small feathers, possibly secured from a dead bird, for it is improbable that these delicate little mammals could successfully overcome a sleeping bird, even though it also be of diminutive size. I have seen juncos sleeping among the *Taxus* clumps when examining my shrew traps at night.

During the summer months the principal food of the shrews appears to be insects, but the stomachs of at least two taken during July contained a mass of flesh and fur. Again it seems improbable that the animal was not a victim of the shrew, but rather met its death in some other manner. None of the trap victims had been touched, however, upon the occasion when these two were taken. Snails, small earthworms and a quantity of vegetable matter have been recognized in autumn specimens but the food appears to differ little from that of the summer.

TABLE II.

Food habits of *Sorex fumeus*, determined from examination of 168 stomach analyses made throughout the year. The figure below the month indicates the number examined. Other figures denote the percentage frequency of occurrence of the different food items.

Food	Jan. 4	Feb. 5	Mar. 14	Apr. 27	May 20	June 16	July 19	Aug. 8	Sept. 17	Oct. 21	Nov. 11	Dec. 6	Total 168
Insects	75	80	85.7	77.7	70	93.7	94.7	100.	88.2	52.4	81.8	66.6	80.0
Earthworms	..	..	7.1	14.4	15	6.2	10.5	12.5	...	9.5	23.3	...	10.1
Vegetable	50	20	14.1	14.4	25.0	18.7	5.3	50	...	...	18.2	50	14.9
Centipedes	25	..	21.4	18.5	5.0	18.7	15.8	...	5.9	9.5	18.2	16.6	13.1
Snails	..	20	...	11.1	10.0	...	10.5	...	17.6	23.8	9.1	...	10.1
Salamanders	..	..	...	3.7	5.0	...	5.3	...	...	...	...	...	1.8
Mammals	..	..	...	3.7	10.0	...	10.5	...	...	...	...	...	3.0
Sowbugs	..	..	...	11.1	...	6.2	21.1	...	...	...	9.1	...	5.3
Spiders	..	20	...	14.4	10.0	6.2	...	12.5	...	...	9.1	...	5.9
Birds	..	..	...	...	5.0	...	...	...	...	...	...	...	.6

Food Requirements. On several occasions I have had captive smoky shrews for variable periods and have observed their feeding activities. These shrews are not the prodigious feeders that many naturalists would have us believe; they never eat food equivalent to their own weight daily, at least in captivity. Nevertheless, Dixon (1924) has demonstrated that the little gray shrew (*Notiosorex*) will eat 75% of its own weight each day. Blossom (1932) observed that a captive female *Sorex cinereus*, weighing 3.6 grams, ate an average daily weight of 11.7 grams, that is, an average of approximately 3.3 times its own weight every twenty-four hours. Wahlstrom (1928) states that the food requirements of *Sorex vulgaris* are enormous and the ability to fast, even when the animal is in good health, is very low. On the other hand, Rorig (1905) maintained that a small amount of food was quite enough to maintain a captive *Sorex araneus* in good health. The shrew ate an average of 7 grams of mealworms, grubs and flesh, and was maintained for nearly three months. Inasmuch as an adult shrew of this species weighs about 12 grams, it may be seen that slightly more than half of its weight in food each day is sufficient to keep the animal in good health.

It may be that conditions under which captive shrews are kept determine their ability to survive on a moderate amount of food. Moreover, a varied assortment of *natural* foods appear to keep the captives more contented than a restricted diet of mealworms or cockroaches. My captive shrews had an assortment of small snails, mouse flesh, small earthworms, beetles, centipedes, sowbugs and siftings from the forest floor, including many spiders. All seemed to do well on this variable diet, and maintained themselves many days on an amount not exceeding half of their weight. Still, this quantity is an incredible amount for such a diminutive animal to consume. Much of the food is bulky and indigestible, for the chitinous remains of the prey pass with the feces in a state which frequently makes identification of the parts quite possible. The shrews eat at all hours, the only stay to their hunger being the necessity for short naps and the actual search for food, which seldom appears to entail any great labor.

Feeding Habits in Captivity. The most important sense utilized in searching for food appears to be that of touch. While hearing is rather acute, sight and smell seem to play a minor role, and the ever moving snout and long vibrissae probably are of major importance in apprising these shrews of their food. They utilize the burrows of many small forest rodents and the larger shrews, and within the confines of these tunnels the small prey has little chance to avoid capture. Moreover, the leaf mold may be riddled with their temporary tunnels and it is suspected, from the actions of captive specimens, that much of their prey is secured by the sensitive nose. Small prey, like flies, tiny isopods and centipedes, soil worms and the lesser beetles are merely bitten and swallowed. The larger food items, as earthworms, snails, salamanders or newborn mice are held down with the fore feet while pieces are bitten off. Wireworms, mealworms, the larger beetles and kindred prey are first paralyzed by being bitten in the head. Small salamanders (*Plethodon cinereus*) are held firmly to the ground and quickly destroyed by being bitten in the head or back, severing the spinal cord. The feet, head and viscera of these amphibians are first eaten, the remainder often being neglected for other food.

It appears improbable that these small shrews are capable of overcoming deer mice and the other small rodents which inhabit their domain. A small *Peromyscus*, weighing 14 grams, was liberated in a large aquarium with an adult *fumcus* weighing 10 grams. The shrew made several abortive efforts to capture the mouse, and once closed in, grasping its active prey by the flank. The mouse immediately broke this hold, and the discouraged shrew thereafter paid no heed to its intended victim.

Sorex fumeus probably obtains sufficient water from its food, for captives drink only a limited quantity, dipping the snout into the pan of water and tilting back the head like a chick. Blossom (1932) gave no water to his captive *S. cinereus* over nearly a three month period. Wahlstrom (1928) found his captive *Sorex vulgaris* never drank; indeed they seemed to fear the water, and one shrew upon falling into its drinking receptacle avoided it thereafter. On the contrary, captive specimens of *Sorex araneus* observed by Wilcke (1938) drank very freely, in fact after every meal.

REPRODUCTION.

Male Reproductive Organs. The following description is based on the genital organs of a sexually mature male (Plate II, Fig. 3). The testes are oval and measure 4 by 8 mm. but occasionally are larger. The caput epididymis is often diffused and ill defined and usually partly embedded in a mass of yellow fatty tissue. The cauda epididymis is large, and in breeding animals the convoluted tubules may be distinctly seen with the aid of a low powered binocular microscope. If the tubules are visible through the walls of the epididymis, they invariably contain sperm. This serves to determine whether the males are in a breeding condition. The proximal end of the vas deferens commences as a narrow tube, gradually swelling until its distal two-thirds is reached. Here a prominent constriction occurs, the distal part being enormously swollen into a pouch which gradually tapers until its junction with the urethra is reached. The distal swelling has a diameter 4 or 5 times as great as the tubal portion of the vas deferens. A similar condition prevails with *Blarina*, but is never so well marked. According to Brambell (1935) these swellings are composed of alveolar pouches which store sperm. During the spring, one can slit the distal pouches and make a smear which usually contains numerous sperm. Two large paired organs, with numerous villi, somewhat larger than the testes, and lying dorsad to the vasa deferentia and the bladder, have been designated the prostate glands by Arnäck-Christie-Linde (1907). These nevertheless appear to be the seminal vesicles, for they appear essentially the

same as these latter structures in other small mammals. Their true homologies cannot be determined until a careful developmental study is made of these and associated structures in several insectivores. The large bean-shaped Cowper's glands, about two-thirds the size of the testes, lie at the base of the tail, and dorsally give one the impression of anal glands. The penis is a large organ for so small an animal. When retracted it is folded on itself so that the tip lies over the most proximal portion. When extended, it measures 16 to 18 mm. There is a suggestion of diffuse prepuccial glands but no ducts are visible. The penis is without a baculum.

Weber (1898) implies that the testes in the Soricidae leave the pelvic cavity seasonally or voluntarily. I have never found the testes situated other than in a cremaster sac outside the pelvic cavity and lying near the dorsal tip of the pubis. Even in very young shrews, the testes may be teased into view with the forceps by grasping the sac and drawing the testes out. In immature shrews, the caput epididymis is more prominent than the testis, both in size and in the lighter color. Apparently the enlargement occurs within the sac, without change of position of the testes during their enlargement.

The increase in size of the reproductive organs at the onset of the breeding season must occur with great rapidity. Specimens secured in March have either very minute testes whose associated structures are barely visible macroscopically, or else the organs are much enlarged. From extensive field observation and dissection of more than a hundred males taken in the late winter or early spring, I should judge that the enlargement of the testes, seminal vesicles and Cowper's glands does not occupy more than 3 or 4 days.

The Female Reproductive Organs. The female reproductive organs of *Sorex araneus* have been well described by Brambell (1935). These organs in *Sorex fumeus* (Plate II, Fig. 4) do not differ markedly from the former species. Inasmuch as these organs are often of minute size, and their parts not easily determined, it seems desirable to give a brief description of them so that American investigators may recognize the different structures.

The ovaries of immature and anoestrous adults are minute, oval yellowish bodies, measuring no more than 1 mm. in length. The much larger ovaries of breeding animals appear like small mulberries, with corpora lutea and follicles projecting above the surface. The corpora lutea, numbering 2 to 5 for each ovary, often occupy the entire ovary. A prominent periovarian sac completely invests the ovary. The oviduct is well marked from the uterine cornu, its ovarian part having a much greater diameter than the uterine end. The entire oviduct is bent in the form of an S. Brambell (1935) states that the Fallopian tube passes diagonally through the uterine wall and projects slightly into the uterine lumen. When stretched taut, the uterine horns join at right angles to the elongated vagina, but when in situ they are coiled and thus occupy little space. The vagina is unique in being bent back upon itself, the distal portion lying dorsad to the proximal portion, so that the junction of the vagina with the uterine horns lies near the site of the bladder. This is an adaption for the excessive length of the vagina which, if it lay in position similar to other small mammals, would reach nearly to the kidneys. The lower part of the vagina merges into the urogenital sinus, where the urethra opens. The clitoris is not well marked.

The three pairs of teats are inguinal, their glands occupying much of the post abdominal and inguinal region in lactating individuals. The first pair of glands are by far the largest, occupying a large area in front of the thighs and extending almost to the sacral vertebrae. In immature shrews and anoestrous females they are small and inconspicuous.

The Breeding Season. The season of reproduction normally extends from early April into August.

Males. Males secured in January and February are all immature, weighing from 4.2 to 6 grams. The testes of these animals are minute and contain no sperm. In order to determine what individuals were fecund, the testes were removed, freed from all extraneous tissue and weighed. Microscopic examination of the epididymis was made to determine the presence or absence of sperm. It was soon evident that size of testes and macroscopic examinations of the epididymis were sufficient to determine fecundity. When the combined weight of the testes exceeded 75 milligrams, they invariably contained mature and abundant sperm. Those individuals which were not fecund had small testes, seldom exceeding 2 mm. and together not exceeding 10-15 milligrams. Sexually mature individuals possessed testes measuring 4×6 mm. to 4.5×8 mm. and the pair weighed from 105 to 145 milligrams.

The change in size of the testes and the increase in weight of the shrew at the commencement of the breeding season is accomplished with great rapidity. Several specimens taken in mid-March of successive years weigh only 5 or 6 grams and have minute testes. During the last week of March a number have been secured weighing 8-11 grams and containing enlarged descended testes which have numerous sperm. On the same dates a few have been collected which still retain their small obscure testes and give no indication that they will, in a few days, become fecund. I have taken no immature shrews from early April until early June. All males secured during this period have had enlarged testes, with swollen vas deferens and seminal vesicles (Plate II, Fig. 3). Adult males continue to maintain their fecundity through August, and the only adult captured in early September likewise had enlarged testes and abundant sperm.

Females. The females, like the males, are all immature during January and February, and show little sexual activity during March. Four females collected on March 29 weigh 6.7-10 grams, and all but one show no sign of breeding. This individual has a swollen uterus and indicates sexual activity, but there are no corpora lutea nor any sperm in the vagina. Nine females collected from April 12-14 are, judged by weight, mature animals but none were pregnant. Shrews taken on April 22 contain embryos measuring from 1-7 mm. Individuals taken on May 1 contain embryos but are not nursing. On May 5 I took 2 females, one of which contained five 5 mm. embryos and another which was actively nursing. The uterine horns show only faint placental scars, so parturition probably occurred prior to May 1.

Mating may follow partus as it does with numerous cricetine rodents, for a large female taken on May 16 was actively nursing and contained eight 2 mm. embryos. Two other females taken on the same date were nursing but were not gravid. In late May a number of lactating females have been examined, but none of these were pregnant. Twenty-four adult females taken during June were all in breeding condition. Of these, 4 were pregnant and the remainder were nursing individuals. Thirteen adult July females were all nursing, and 2 were pregnant. During August, adult shrews become increasingly scarce, only one of the 4 adult females which were examined during the second week of this month being in a breeding condition. No breeding occurs during September. An interesting instance of October breeding is given by Green (1930) who took a recently nursing shrew on October 11 at Ricketts, Pa. This is a most unusual circumstance and is difficult to explain, inasmuch as I have examined 68 females during this month, and all have been immature animals.*

From these data it may be seen that males become fecund earlier in the spring than the females, and individuals usually continue in a breeding condition after the females have all died or at least ceased to breed. It is thus concluded that the female controls the breeding season, a condition

* Of 32 females taken at Ithaca, N. Y., from Oct. 3-10, 1940, one was a recently lactating adult.

similar to that of *Blarina*, *Peromyscus* and several other small mammals which I have studied.

Duration of Pregnancy. Little data are at hand regarding the gestation length of shrews. This is, in large measure, due to the difficulty of keeping these animals in captivity a sufficient time to breed and thus observe the gestation period. *Blarina* has a probable gestation period of 21 days (Hamilton, 1929). According to Brambell (1935), the probable gestation of *Sorex araneus* is between 13 and 19 days, with a similar lactation period.

If sufficient numbers of adult females are examined prior to the inception of the breeding season, and suitable samples obtained at several day intervals, it is possible to estimate the probable length of the gestation. Prior to April 15, no pregnant shrews have been secured, although more than 20 individuals have been examined from March 15 to April 15. On the latter date, vaginal smears from one individual indicated the shrew was in oestrous. On April 22 and 23, shrews which I examined contained embryos having a crown-rump measurement from 1 to 7 mm. On April 26, 29 and 30 and on May 1, several shrews contained embryos measuring, from 3 to 10 mm. The earliest records of lactating shrews occur on May 5, when 2 nursing specimens were secured. One had faint placental scars while the other had produced young very recently. Females taken on May 3, 5 and 9 were all actively lactating.

If the earliest pregnancies occur on or about April 15 (based on the 7 mm. embryos secured on April 23) and the earliest parturition date on or about May 4, this would place the gestation length at approximately 3 weeks. It appears likely that the gestation of this shrew is no longer than 3 weeks duration, and probably somewhat shorter.

Litter Size. Based on counts of embryos and placental scars in 42 females, the litter size averages 5.5 embryos per female. Absorption of the embryos occasionally occurs, particularly in the late litters so that an embryo count is not a positive criterion of the young actually produced. Nevertheless, the six mammae suggest that 5 or 6 young are the usual number born (Plate III, Fig. 5). The largest embryo count was 8, the smallest 2. Middleton (1931) has shown that the litter size of *Sorex araneus* becomes smaller in July, at the close of the breeding season. One might suppose that as the females became senile and approached death during mid- to late summer those continuing to breed would have smaller litters. Such diminution is not well marked. In April the litter size, based on embryo counts, was 5.8. During May it averaged 6.2; for June, 5.5, and for July, 4. A July 12 female contained 2 embryos. The single pregnant August female contained 6 embryos, one of which was being resorbed, while a lactating shrew taken on August 12 had 4 placental scars.

DERMAL GLANDS.

Side Glands. All soricids possess side glands, small oval areas of agglutinated hairs on the side of the body midway between the fore and hind limbs. These glandular areas are composed of enlarged sweat glands lying in the deeper part of the corium of the skin and of large sebaceous glands above the sweat glands in the upper portion of the corium (Eadie, 1938).

Arnbäck-Christie-Linde (1907) found side glands restricted to the male in *Sorex vulgaris* and *Crossopus fodiens* but present in both sexes in *Crociodura*. Both sexes of *Sorex fumeus* possess these glands, although they are better developed in the male than in the female. The glands may not be evident in immature females, whereas in immature males the glandular areas are always marked on the flesh side of the skin.

A noticeable enlargement of the side glands occurs in the late winter,

coincident with the enlargement of the reproductive organs. The glands then become highly vascularized (Plate III, Fig. 6) and are evident as large reddish patches on the skin surface. Johnsen (1914) believes the scent glands, at least in the male, play an important part in the sex life of the animal. He has observed that in male shrews, the growth of the sweat glands and preparation of the secretory stages parallel the ripening of the testes. This condition certainly obtains for *Sorex fumeus*. Throughout the breeding season, the glands remain prominent in both sexes, although non-breeding adult females do not exhibit pronounced glands.

The function of these glands is problematical, but it seems possible they act in some manner to attract the sexes during the breeding season. Their relation to reproduction is evident, for only at this season are the glands well developed.

On June 12, 1932, I captured a female smoky shrew in a tin trap. The animal had been dead a short time. As I was standing near the trap, a shrew appeared in the runway, ran about the trap several times and appeared to be much excited. Its side glands were very evident, the hairs about these structures being laid back so that the semi-glabrous glandular area could readily be seen. No odor was visible until I knelt down and smelt closely of the burrow it had occupied, when the peculiar and characteristic smell of this shrew was quite evident.

LIFE SPAN.

It has long been apparent that the long-tailed shrews caught at periods other than the spring and summer months (late March to early September) were all immature individuals. A critical examination of these specimens suggests that the smoky shrew does not become mature until late winter and almost the entire adult shrew population dies during the late summer.

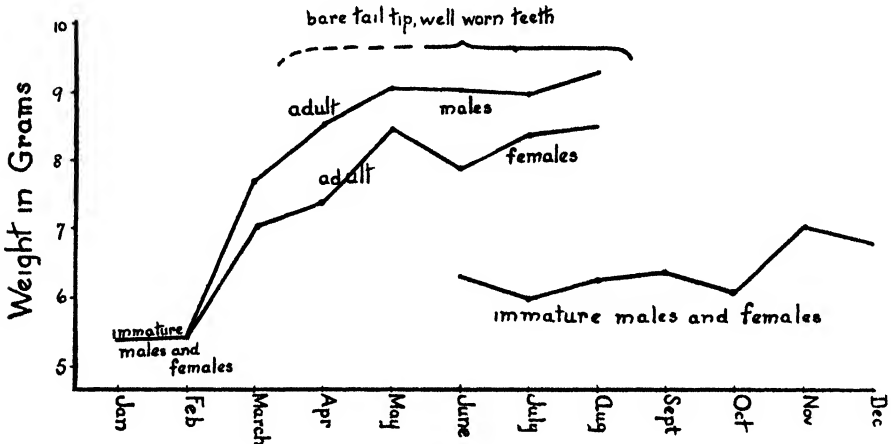
Many observers have remarked on the supposed autumnal mortality of *Sorex*, but Adams (1910) was the first to suggest the true cause. He could trap no adult males nor females after December, and concluded that the autumnal epidemic is due to nothing other than old age, this being reached in the case of *Sorex araneus* and *S. minutus* in thirteen or fourteen months. Middleton (1931), apparently unaware of Adams' study, reached a similar conclusion, viz., that all adult shrews (*Sorex araneus*), following the short but prolific breeding season, gradually die out, so that none are left by the following winter. Recently Brambell (1935), from a study of 1,064 trapped shrews (*Sorex araneus*), likewise concludes that the females live over a single winter only and die at the close of their first breeding season, the year following that in which they were born, and that the young males do not breed in the season in which they were born, and do not live over a second winter.

Montague (1922) questions the abundant testimony in support of this short life span, for a specimen of *Sorex araneus grantii* which he collected in June appeared to be undoubtedly above normal age, the teeth being almost completely worn away, while the coat is grizzled.

Certain distinguishing characters readily separate the immatures from the adults of *Sorex fumeus*. Shrews weighing 7 grams or more may be considered adult. Those with glabrous tails, the tip more or less rounded and blunt, with few or no hairs and often with numerous scars, may be considered adult. Prominent tooth wear is characteristic of adult shrews (Plate IV, Fig. 8).

Perhaps the most distinctive feature of young shrews is the general hairy condition of the tail, particularly at its tip. In young shrews, this member retains its hairy condition until April, when the shrews are eight to eleven months old (Plate III, Fig. 7).

During the year in which they are born, none of these young shrews become sexually mature. I have carefully examined the reproductive organs of more than 300 fresh immature specimens, and all indicate a quiescent stage, in which the testes are minute, seldom exceeding a millimeter in length, and the ovaries microscopically showing no indication of sexual activity. Moreover, I have collected only one adult shrew later than the first of October. It is probable that a few adult females live into the fall, for Green (1930) secured a nursing *Sorex fumeus* in northern Pennsylvania on October 11, 1927. Brambell (1935) states that immature females of *Sorex araneus* may exhibit signs of precocious sexual activity in the autumn of the season in which they are born. Even though follicular growth and vaginal cornification occur there is no evidence that these immature shrews become functionally mature. Such animals gradually pass into the typical winter condition.



Text-figure 1.

Graph demonstrating the relation of weight to age. A pronounced acceleration in weight is evident in March, when both sexes, which have overwintered as immature individuals, become sexually mature. From April to September, adults may be recognized by the increasingly worn condition of the teeth and the glabrous condition of the tail. The pencil of hairs is usually lost in May or June, but a few may be retained into August. It may be seen that the adult shrew population dies during August. A few may survive into the fall, but such is most unusual. The immature shrews lose weight in mid-winter, but their transition in March from immaturity to adults is remarkably rapid.

Examination of Text-figure 1 will show the marked disparity between the weights and tail condition of immature and adult shrews. We may thus conclude that, with *Sorex fumeus*, all of the adults, after completing their reproductive duties, die of old age when they are fourteen to seventeen months old.

POPULATIONS.

Our small native mammals are, for the most part, cyclic in nature, their populations varying from year to year. Some seasons they may exist in considerable numbers, while in other years only a few may be trapped.

During July and August, 1938, I trapped various habitats on the Huyck Preserve at Rensselaerville, Albany County, New York, to determine population levels of small mammals. In the more favorable habitats of beech and hemlock, with ground cover of *Taxus* and broad leaved herbaceous species, deep leaf mold and litter, I established several quadrats measuring

100 by 100 feet (.23 acre). Within these areas 300 traps were placed in the most promising runways, particularly in subterranean burrows and trails beneath the leaf mold. These traps were visited at dusk and dawn for a three-day period, or until the catch had been so reduced it was assumed the major part of the population had been removed. On one of these quadrats 65 small mammals were taken in three nights, 12 of which were *Sorex fumeus*. On another plot in similar habitat a quadrat yielded 68 small mammals, 10 of them being *Sorex fumeus*. In an open, sparsely wooded second growth stand of beech, maple and hemlock, with thick carpet of leaves and moss, 41 small mammals were collected on a quadrat. Six of these were smoky shrews. Thus on three quadrats of nearly a quarter acre each, there were 12, 10 and 6 smoky shrews collected, or an assumed average population of between 25 to 50 *Sorex fumeus* per acre. This was in the very best shrew habitat. One well wooded ravine, with a permanent cold stream and with black loamy slopes covering loose rock, appeared to be particularly attractive to these shrews. Yellow birch, mountain and striped maple, hemlock, witch hobble, with ground cover of liverworts, mosses and forest perennials, provided a cool retreat, and the black friable soil supported a particularly rich invertebrate fauna. In 1937 I trapped 70 *fumeus* during a three-week period in an area scarcely exceeding 1.5 acres. This intensive collecting had its effects, for a brief trapping period in 1939 indicated the population had been much reduced.

These high populations are exceptional, and are only met with in the most suitable habitats during years when shrews are numerous. In 1936 several quadrats in a beech woods near Ithaca, New York, on which I collected produced an estimated population of 9 and 14 *fumeus* per acre respectively.

While these shrews exhibit definite variable populations, and give every indication of being cyclic, I am not certain how long the cycle runs its course. About Cleveland, Ohio, Bole (1939) finds the smoky shrew very susceptible to drought, and believes they are affected by cycles as well. During the 1937-38 *Sorex* peak their numbers were estimated at 58 per acre, one of the highest ever discovered for any species by Bole. He remarks that in habitats other than climax forests this shrew is distinctly uncommon, the average being less than 1 per acre. Wherever I have found *Sorex fumeus*, the population has never been this low, although it is probable in some of the areas which I have trapped in western New York, the numbers of smoky shrews would not exceed 5-6 per acre.

The autumn population is composed almost entirely of young shrews, and as no breeding occurs from September until April, there is naturally some attrition during this season. Some years it may be rather high. Collecting was conducted on Connecticut Hill, near Ithaca, New York, in beech-hemlock woods with deep leaf mold. Traps were grouped in lots of 5-10 about stumps, beneath fallen logs, in leaf mold runways and kindred places. In 1,000 trap nights 155 mammals were collected, 17 being *Sorex fumeus*. During the first week of May, 1939, a similar trap line, in comparable habitat and under similar conditions was attended with markedly less success. Forty-six mammals were taken, of which 4 were *Sorex fumeus*. The population increased decidedly during the summer. From October 3 to 8, 1939, a thousand trap nights under situations comparable to the previous year produced 101 mammals, but of these 30 were smoky shrews. During the first week of May (May 1-5), 1940, the same number of traps produced 28 specimens and 6 of these were *fumeus*.

Thus we may conclude that, in these two years, scarcely more than 20 to 25% of the shrew population survived the winter. The winter mortality does not appear to be so great with the smaller rodents and *Blarina*, but even with these the loss may be 60% of the entire population.

ENEMIES.

Every small abundant mammal has a host of enemies; the smoky shrew has proved to be no exception.

The larger predators, such as the fox and bobcat, are known to capture and eat *Sorex*. Indeed the only item in the stomach of a large Vermont bobcat which I captured contained the entire body of a *Sorex cinereus*, and it is unlikely that they would shun *fumeus*. Hawks and more particularly owls, are known to prey upon them. Fresh pellets from a nesting pair of long-eared owls collected during June, 1926, near Ithaca, New York, contained the skulls of this species. Weasels capture considerable numbers of the long-tailed shrews (Dearborn, 1932; Hamilton, 1933). All of these larger predators probably make serious inroads on the shrew population but there is a more deadly and ubiquitous predator which possibly levies a fearful toll, and may be, in part, responsible for drastic reductions in the *Sorex* population. I refer to the ever-present *Blarina*, which may weigh two to four times as much as its smaller relative. Its greater size and formidable dentition are more than a match for the largest and strongest *fumeus*. On May 18, 1938, I caught a 20 gram *Blarina* whose stomach contents consisted entirely of the fur, flesh and toes of a smoky shrew. No *Sorex* had been captured in nearby traps, so it is good presumptive evidence that *Blarina* had overpowered and devoured its lesser kin. It is not without reason to suspect that this happens not infrequently in areas occupied by both species.

Parasites. The following parasites have been determined by the staff of the Bureau of Animal Industry, U. S. Department of Agriculture.

One seldom encounters a shrew without its quota of ectoparasites. Fleas are seldom found, and are never as abundant as they are on the larger *Blarina*. The only fleas which have been recovered from the smoky shrew are *Ctenophthalmus pseudagyrtes* and *Doratomylla blarinae*, both commonly found on *Microtus*, *Peromyscus* and *Blarina*. Mites of the genus *Myobia*, *Haemogamasus* and *Protomyobia* (probably *P. clarapedi*) are often abundant, and immature individuals may exceed a hundred to a shrew. The small gamasid species burrow into the skin, particularly about the ears and vent, and these are the parasites which cause inflammation and pruritus. The anal region is often extensively scarred and pitted by the action of the mites.

Endoparasites apparently are restricted to a few nematodes. One, *Porrocaecum* sp., is found coiled in a sheath among the muscles, the external walls of the stomach and attached to the viscera generally. It is a sizeable roundworm, measuring 40 mm. or so in length, and there may be 10 or 12 when the infestation is heavy. It is thought that the adults occur in birds of prey but no experiments have been conducted to demonstrate this. Similar roundworms occur with great frequency in *Blarina*.

SUMMARY.

A life history study of the smoky shrew, *Sorex fumeus*, in New York has been made over the past ten years to secure data on the biology of this little known species. Five hundred and sixteen shrews have been examined in the flesh and a number of captive animals have been studied, providing much new information on their biology.

It is shown that external measurements are of little value in determining age classes, but weight is of decided value, readily separating immature from mature individuals.

The smoky shrew undergoes a biannual molt. The change from the

gray winter pelage to the brown summer pelage occurs from late April until late June, and the fall molt occurs from mid-September to early October.

The smoky shrew is a northern species, attaining its greatest abundance in the cool forested regions of Pennsylvania, New York and New England. It is most numerous in the hardwood and coniferous forests which have a deep leaf mold.

This species is active at all hours. It is found in company with several other small mammals, whose runways it occupies. These associates are *Blarina brevicauda*, *Sorex cinereus*, *Peromyscus leucopus* and *P. maniculatus*, *Clethrionomys gapperi*, *Synaptomys cooperi*, *Napaeozapus insignis*, *Parascalops breveri* and several other species. In the habitats of this shrew where collecting has been most extensive, *Sorex fumeus* represents 18.3% of the small mammal population.

Little burrowing is done by the smoky shrew; it appears to occupy the runways of other small mammals, building its nests beneath stumps, rotted logs and in the galleries of *Blarina* and various rodents.

Sorex fumeus has diverse little notes, from high pitched grating, bat-like squeaks to indiscernible twitters. Sight and smell are not well developed, hearing is reasonably acute, but reliance is placed on the acute tactile sense.

On the basis of 168 stomach analyses, made from shrews taken throughout the year, it is concluded that insects are by far the most important food, being found in 80% of the stomachs. Vegetable matter was found in 14.9%; snails, 10.1%; spiders, 5.9%; sowbugs, 5.3%; mammals, 3.0%; salamanders, 1.8% and birds, .6%. Captive shrews maintain themselves well on an assortment of natural foods equal to half their weight daily. Captive individuals seldom drink.

The gross anatomy of the reproductive organs are described, attention being directed to the rapid increase in size of these organs at the onset of the breeding season. There are six teats, post-abdominal and inguinal in position. The mammary glands are very large, the first pair nearly encircling the body. The breeding season commences in late March and lasts through August, although only a small number of females breed in the latter month. Inasmuch as males become fecund earlier in the spring and remain so later in the summer than the females, it appears probable that the female controls the length of the breeding season. The duration of pregnancy is assumed to be somewhat shorter than three weeks. The litter size averages 5.5.

Dermal side glands are found in both sexes, but are more prominent in the males. They must bear some close relation to the reproductive period, for only at such a time do they enlarge and secrete the odorous material common to shrews.

The life span of the smoky shrew is short, for all the adults die of old age when they are 14 to 17 months old. This conclusion is based on the fact that no shrews breed in the year in which they are born, but pass their first winter as immature individuals. Weight, degree of hairs on the tail and tooth wear combined are infallible criteria of age, and serve readily to separate the adults from the immature shrews. Following the breeding season, the adult population of shrews die, usually in August.

The smoky shrew is probably a cyclic species, for its numbers fluctuate in different years. The shrew population varies from 5-50 individuals per acre during the late summer, but is much reduced during the winter, only 20-25% of the population surviving.

These shrews have many enemies, including predatory mammals and birds. It is pointed out that *Blarina* may be one of the most important

enemies. Ectoparasites include fleas (*Ctenophthalmus pseudagyrtes* and *Doratomyia blarinae*), mites (*Myobia*, *Haemogamsus* and *Protomyobia*), while a nematode, *Porrocaecum*, is often abundant.

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EXPLANATION OF THE PLATES.

PLATE I.

- Fig. 1. Habitat of the smoky shrew. Beneath half-rotted logs and in the deep leaf mold of beech, yellow birch and hemlock woods, these small shrews are often numerous. In the area shown, twenty smoky shrews have been taken in a two-year period, in addition to scores of deer mice, red-backed mice, woodland jumping mice, short-tailed shrews and an occasional hairy-tailed mole. Ithaca, New York.
- Fig. 2. Head of a freshly killed smoky shrew. The prominent ear, small eyes and long snout with prominent tactile hairs are characteristic of this species.

PLATE II.

- Fig. 3. Reproductive organs of an adult male *Sorex fumeus*. **A**, testes; **B**, caput epididymis; **C**, cauda epididymis; **D**, vas deferens; **E**, distal swelling of vas deferens; **F**, seminal vesicle; **G**, Cowper's gland; **H**, bladder; **I**, penis.
- Fig. 4. Female reproductive tract of the smoky shrew. The uterus shows a condition about two weeks following partus. Four placental scars may distinctly be seen. **A**, suspensory ligament; **B**, ovarian capsule enclosing the ovary; **C**, proximal region of fallopian tube; **D**, uterine cornu; **E**, uterine vessels; **F**, bladder; **G**, diffuse prepuccial glands; **H**, vulva.

PLATE III.

- Fig. 5. Mastology of nursing smoky shrew. The teats are always limited to three pairs in the position shown.
- Fig. 6. Side glands viewed from the flesh side of an adult male *Sorex fumeus* collected on April 19, 1936. A strip of skin has been removed from the back and sides. The highly vascularized glandular area is prominent against the pale hide.
- Fig. 7. Tails of immature and mature shrews. The upper figure is that of an immature shrew taken in October. Note the well-furred tip. The lower figure is that of an adult male collected in April. The absence of hairs on the tail tip and the eventual loss of hair over the entire tail, in addition to the scarring, is an indication of maturity.

PLATE IV.

- Fig. 8. Tooth wear in *Sorex fumeus*. **A**, an immature specimen collected on June 11 at a probable age of one month; **B**, immature shrew taken in November; **C**, sub-adult shrew collected in March, showing the prominent wear resulting in almost total loss of the brown tipped hooks of the first incisors; **D**, characteristic tooth row of mature shrew, as indicated in July and August specimens. The teeth of these old shrews have all lost their brown tips.



FIG. 1



FIG. 2

THE BIOLOGY OF THE SMOKY-HREW (*OREX F. MEL'S MILLEP*)

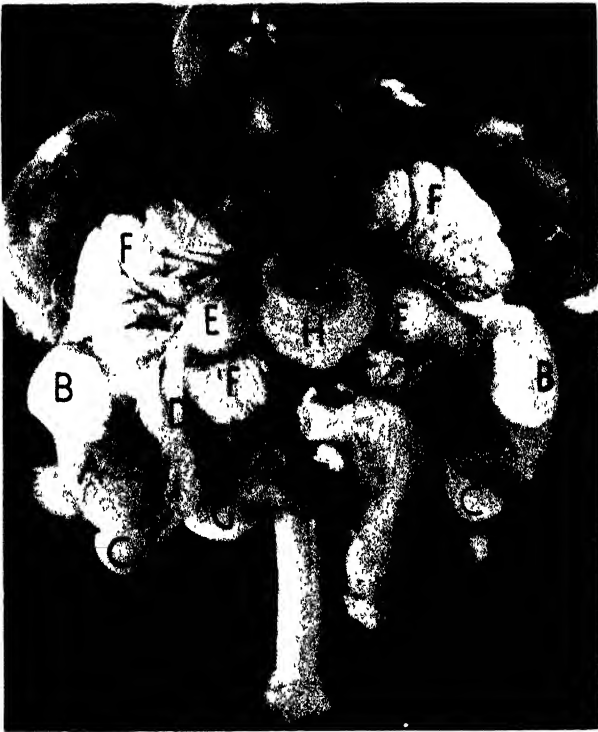


FIG. 3



FIG. 4

THE BIOLOGY OF THE SMOKY SHREW (*Sorex fumeus* MILLER)

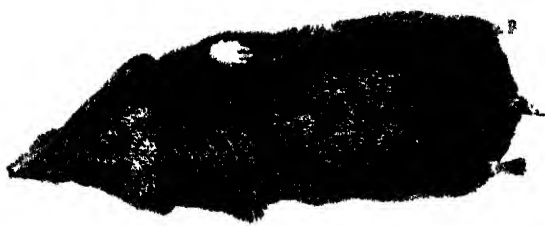


FIG. 6



FIG. 7

THE BIOLOGY OF THE SMOKEY BREW (OREXIA MEYER MILLER)

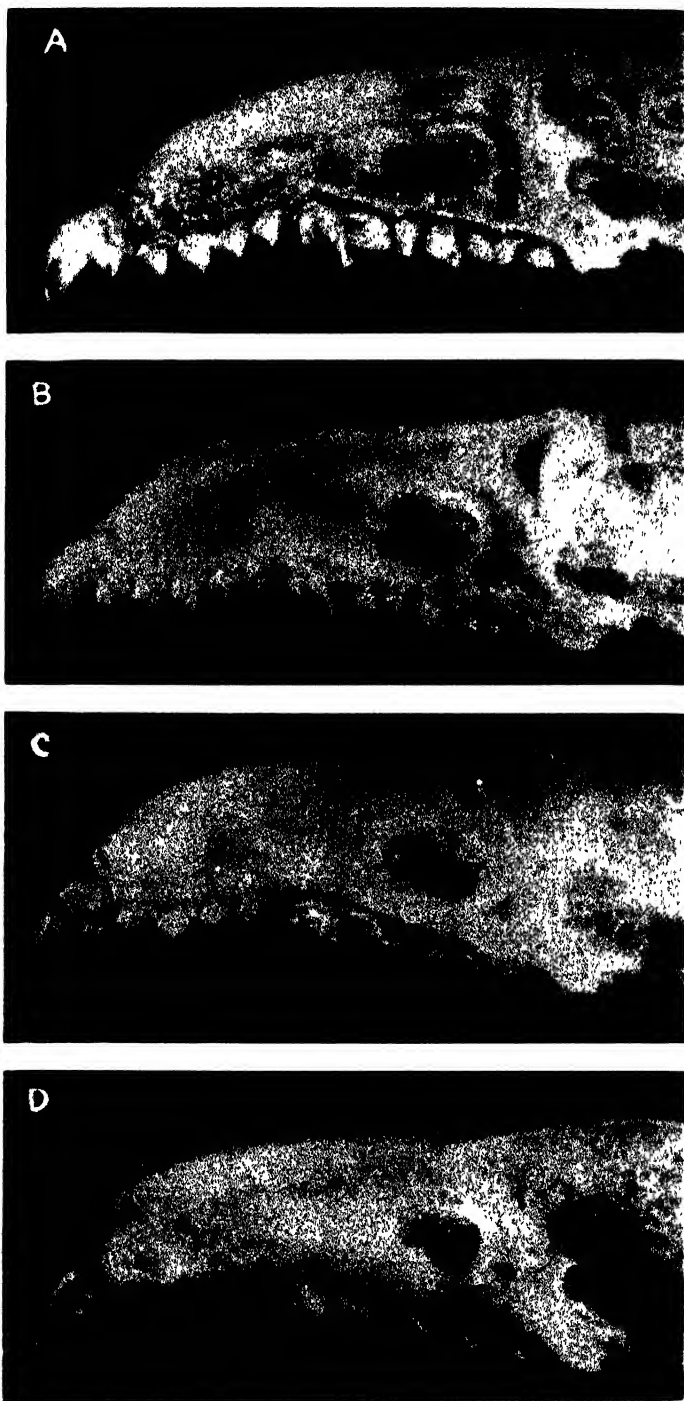


FIG 8

THE BIOLOGY OF THE SMOKY SHREW (*SOREX FUMEUS* MILLER).

30.

Social and Respiratory Behavior of Small Tarpon.

ARTHUR SHLAIFER & C. M. BREDER, JR.

New York Aquarium

(Plates I & II; Text-figure 1).

INTRODUCTION.

As part of the program covering a study of the life history and habits of the tarpon, *Tarpon atlanticus* (Cuvier & Valenciennes), a number of small specimens were brought to the laboratories of the New York Aquarium. These were shipped from the field station of that institution on Palmetto Key, Florida, for laboratory study. They had been collected on Sanibel Island by Mr. Marshall Bishop (Breder 1939 a and b).

A consideration of the social attitudes and respiratory behavior of these specimens forms the basis of the present report. These studies have been reinforced by others made in outdoor pools, both in New Jersey and at the Florida field station.

Aside from the actual details which this study works out, the suitability of small tarpon for laboratory work early became apparent. In addition to a most remarkable hardihood, the peculiar specializations of this species lends itself, to a remarkable degree, to a variety of purposes. Some of these will become apparent on a consideration of the body of the report.

For the chemical analysis in Table X by the laboratory of the Bureau of Water Supply of New York City under the direction of Dr. F. E. Hale, we wish to express our thanks. We also wish to thank Mr. R. S. Mathews of the New York Aquarium for assistance during the course of the work.

MATERIALS AND METHODS.

In order to obtain some measure of the attitude of one fish to its fellows, two methods of approach were employed. One consisted of estimating the locomotor behavior of the fishes and the other of estimating the extent of imitation in the specialized respiratory behavior of this species.

The first method, that established by Schuett (1934) and Escobar, Minahan & Shaw (1936) and subsequently used by others, consists of estimating the amount of locomotor activity by noting the travel in a given period of the fish under observation by means of projected cubes from rulings on the glass walls of aquaria.

In these experiments rectangular metal framed aquaria of 50 liters capacity, measuring 60 x 30 x 27 cm. and containing 48 liters, were used. The four sides, which were of transparent glass, were ruled in 8 cm. squares and two mirrors were used to observe movements at the ends. Observation periods of 15 minutes were employed, the distance covered being computed from the number of projected 8 cm. cubes the fish passed through

in that amount of time. The centimeters traversed were obtained by multiplying by 8 the number of cubes traversed.

Each fish was observed for 15 minutes of each hour of a three-hour experimental period. The tarpon used in each day's experiments were selected from a group of ten specimens of the same size, about 10 cm. from the tip of the snout to the base of the tail. In general, experimental tarpon were alternated every day between the various experimental conditions of a particular series so as to distribute evenly any possible daily variations. No observations were made until at least 21 hours had elapsed after a tarpon had been placed in an experimental arrangement. The tarpon were fed chopped herring three times a week at the close of the day's experiments. In general, new water was used at the start of each set of experiments and was not changed during the course of their running. When such water was not oxygenated artificially the oxygen content was 2.0 to 2.7 cc. per liter. When oxygenated it ran from 5.6—5.8 cc. per liter.

Day by day laboratory results for all experiments were checked against the daily barometric pressure readings of the U. S. Weather Bureau, whose New York City station is located one block from the New York Aquarium. No correlations were obtained.

Tarpon respire atmospheric oxygen and for that reason rise to the surface to gulp air at more or less definite intervals. Since this feature might be useful in estimating metabolic activity, such behavior was noted along with the locomotor activity. A marked tendency to rise in groups was evident and this association of fishes in their respiratory movements was likewise studied. Since it is possible to make such studies in the field, observations on the rising of tarpon not confined in small aquaria were also taken for comparison. These field observations on rising tarpon were made in part in a private garden pool of fresh water in northern New Jersey and in part in a pool at the New York Aquarium's Florida field station. The New Jersey pool, of irregular shape, has a surface of 15 square meters and is about 60 cm. deep in its deepest part, and has a volume of 4,300 liters. The water is standing, additions being made only for evaporation, and is for most part crystal clear. The Florida pool is nearly rectangular in outline and has a surface of 115 square meters and is 1 meter deep in its deepest part. The water is standing, supplied only by rain except on the highest spring tides when sea water enters it through a narrow channel. The color is a deep tan. The volume of water is 70,000 liters.

RESULTS OF OBSERVATIONS ON AQUARIUM MATERIAL.

Data obtained in the laboratory, together with their statistical analysis, are given in Tables I to V. Considering only the locomotor portions of these tables, it is evident that under the conditions of these experiments there is little or no significant difference in the locomotor activity between solitary or homotypically grouped tarpon, excepting only some indications of minimal activity in groups of two. This is in contrast to the marked differences found in other species where large differentials have been obtained. Heterotypic groups of tarpon and goldfish indicated a considerable increase in the locomotor activity of the tarpon in association with the normally more active goldfish.

Tables I to V also give the data on aquarium observations of the respiratory efforts. Like the locomotor-activity figures, these show little if any significant relationship between rises for air and various degrees of homotypic grouping. Heterotypic grouping with goldfish shows a general increase in this type of activity paralleling the increased locomotor index.

There appears to be an imitative factor in this rising to the surface for air, as the number of nearly coincidental rises in a group shows a well

marked mathematical significance. Furthermore, it will be shown that models properly manipulated will induce such rises.

Effect of Isolation, Grouping and Tonicity on Locomotor and Respiratory Activity.

Research on the goldfish, a non-schooling form, by Schuett (1934), Escobar, Minahan & Shaw (1936), Breder & Nigrelli (1938) and Shlaifer (1938) has established the fact that goldfishes are significantly more active when isolated than they are when grouped. Tarpon are, like the goldfish, non-schooling forms; however, they are definitely aggregating forms, more so than are goldfish. Accordingly, it was deemed appropriate to observe the behavior of young tarpon in isolation and in groups as regards locomotor activity. Even in well oxygenated water, tarpon rise to the surface periodically to gulp air. They possess alveolar tissue in their lung-like swim-bladder (Babcock, 1936). This pattern of respiratory behavior was employed as an indirect check on metabolic rate and the air-gulp rate (respiratory activity) was noted. Since tarpon live in both fresh and salt water, experiments were performed in both media to determine whether this difference in the chemical environment of the tarpon was reflected in any way in locomotor or respiratory activity.

The statistical analysis of the data in Table I indicates, in general, that there is no significant difference in locomotor and respiratory activity between a tarpon in isolation and in groups either in fresh or salt water and that locomotor and respiratory activity are, in general, the same in both media. There is, however, some indication of minimum locomotor activity in the group of two in fresh water.

Effect of Heterotypic Grouping.

When individual goldfishes were placed in various heterotypic groups of fishes (Shlaifer, 1940), the decreased activity that obtained in homotypic groups disappeared. It was thought desirable to investigate the effect of heterotypic grouping on individual tarpon, although it must be remembered that a tarpon in a group of four has the same rate of locomotor activity as does one in isolation. Tarpon were observed in isolation, in homotypic groups of two and of four and in heterotypic groups containing in one case the experimental tarpon and three orange-colored common goldfishes 10 cm. in length and in the other the experimental tarpon and three golden shiners, *Notemigonus crysoleucas* (Mitchill), colored olive-green and also 10 cm. in length. In the experiments performed on the goldfish heterotypic group and its control homotypic group, the medium was 90% fresh water and 10% sea water and it was not oxygenated, having an average oxygen content of 2.40 cc. per liter. In the experiments performed on the shiner heterotypic group and its control homotypic group, the water was completely fresh, was oxygenated with compressed air and contained 5.62 cc. of oxygen per liter.

The data in Table II again indicate minimum locomotor and respiratory activity in the homotypic group of two tarpon; especially evident, however, is the greatly increased rate of locomotor and respiratory activity in individual tarpon when in the heterotypic situations. At the same time, the data in Table II and Table III indicate that goldfishes and shiners are much more active than are tarpon. Though goldfishes differ markedly in color and to some extent in form from tarpon, shiners do not show nearly such great differences. It is probably, then, merely the disturbing effect of greater activity by the goldfishes and shiners that is responsible for increased activity in the young tarpon. At no time were goldfishes or shiners observed to chase the tarpon and thus directly affect activity. The data also show a distinctly lower rate of respiratory rises when the tarpon are in the highly oxygenated water used in the shiner experiment and its control.

Effect of Visual Contact with the Same and Other Species.

Shlaifer (1939, 1940) demonstrated that the activity of an isolated goldfish was significantly decreased when it was in contact through vision alone with others of its kind as well as when it was actually grouped with them. This line of evidence helped to establish the fact that the group effect was integrated on a visual basis. When goldfishes were grouped with various other species or were in visual contact alone with them, no diminution in activity obtained (Shlaifer, 1940). Since goldfishes and shiners do produce an increase in the activity of individual tarpon grouped with them, it was deemed desirable to pursue the analysis further by eliminating all factors but vision. Table III indicates the results.

Reference to Table III indicates that visual contact alone with goldfishes will also increase significantly the rate of locomotor and respiratory activity of isolated tarpon. In one case, IV vs. IVa, the increase in rises is not significant but from the trend probably would be so with more data. Cross-comparisons between the first parts of Table II and Table III show no significant differences for isolated fishes and those in a group of four in visual contact or grouped together. Though the volume available to the experimental tarpon in the visual contact experiments is only one-half that in Table II, there is no apparent decrease in activity. Amount of available swimming space undoubtedly affects activity in these forms but not between these limits. It will be noted that the activity of the experimental tarpon in actual grouping with three goldfishes is significantly higher than the activity of a tarpon in visual contact alone with these goldfishes. Thus, it may be concluded that while visual contact with goldfishes is enough to increase significantly the activity of isolated tarpon, it is not as effective as when the tarpon is actually grouped with them directly; presumably this is due to the greater chances for disturbing stimuli in the latter case. Additional data in Table III reveal that the goldfishes used in the experiments listed for this table had the same rate of activity as did those in Table II, although the volume available was reduced by half. The goldfishes were, however, significantly more active than the tarpon.

"Imitation" in Respiratory Behavior.

A very interesting pattern of behavior found in the tarpon is the rising to the surface to gulp air by more than one tarpon at a time in a group of two or more. One tarpon will rise to the surface and its rise may be followed immediately by that of one or more other tarpon. This imitative rise does not occur constantly, but apparently, as further data will attempt to show, only when a physiological threshold has been reached. That such imitative rises are truly imitative and not merely coincidental may be determined by the laws of chance. An imitative rise, or at least what we consider to be one, occurs within a second after the initial rise. The minimum time between the rises of any given tarpon that are not imitative is 300 seconds; in other words, tarpon when most active in water not too well oxygenated will rise only once every five minutes. If they are less active and the water is well aerated, the interval is even greater. The data in Table IV were obtained during the running of other experiments.

The data in Table IV indicate that in a group of two, 36.8% of the time a rise by one tarpon will induce a rise by the other. In a group of four, 69.3% of the time a rise by one tarpon will induce a rise in one or more other tarpon in the group. If imitative rises do not occur at random but only when the animal is physiologically ready for an air gulp, then the results are in accordance with expectations. We find in the group of four that the percentage of induction of rises decreases as the number of fishes rising at one time increases. Presumably, the more tarpon, the less the chance that they will all be in a physiologically receptive state for the induction of imitative rises at the same time. However, comparing the group of two with the group of four it is seen that the larger the group the

greater the chance that the rise of one fish will induce an imitative rise in others. Under "additional data" in Table IV may be found evidence for the visual nature of the imitative rise. We find many cases in which the rise of a tarpon on one side of a transparent glass partition in an aquarium will produce imitative rises by tarpon on the other side.

Effect of High Oxygen Content.

Tarpon in nature may be found in salt water that is highly oxygenated and in fresh or brackish water with very low oxygen content. This experiment was designed to investigate the effect of high oxygen content on the locomotor and respiratory activity of tarpon in the laboratory. In previous experiments the water used was not artificially oxygenated and on the average contained 2.0-2.7 cc. of dissolved oxygen per liter. In this experiment compressed air was constantly bubbled through the water and maintained an average oxygen content in the aquaria of 5.81 cc. per liter.

The data in Table V, part A, again indicate no effect of grouping on activity. There is again some indication of minimum activity in the group of two but no significance statistically. When the data for locomotor and respiratory activity are compared with comparable data in Tables I and II, it is seen that while the locomotor activity is the same at the higher oxygen content, the rate of surface rises is significantly less. Thus when the oxygen content of the medium is higher, tarpon apparently utilize more dissolved oxygen and less atmospheric oxygen.

Effective Limits of the Induction of Imitative Rises.

Observations were taken upon individual experimental tarpon in a group of four in order to determine the mean and extreme ranges for non-imitative and imitative rises by the experimental animals and for rises by the non-experimental fishes which did not induce rises in the experimental. Table V, part B, lists the results.

The mean time for an imitative rise by a tarpon, following its previous rise, imitative or non-imitative, is sufficiently close to the mean time for a non-imitative rise to indicate the importance of a physiological respiratory threshold being reached before a rise by one tarpon will induce an imitative one in another. It should be remembered that we consider a rise by a tarpon imitative only if it occurs within a second after a rise by another tarpon in the group. This is not a purely arbitrary assumption, for if the fish does not rise within one second it usually will not rise for a minute or more. The ranges from lowest to highest are great but most data fall close to the mean. It is not easy to explain these extreme ranges. Probably long periods between rises indicate greater oxygen uptake at the last gulp and very short periods indicate very low oxygen uptake. It will be noted from the column titled "mean activity per minute" that at the extreme ranges in the last column the activity per minute (obtained by dividing the centimeters by the number of minutes) does not differ markedly from these means and hence would eliminate the possibility that very low or very high rates of activity were responsible.

Induction of Imitative Rises by a Tarpon Model.

While it is known that the rising of a tarpon to the surface to breathe air may induce an imitative rise in others in a group, it was thought desirable to determine whether such imitative rises could be induced by objects other than the fish themselves. Accordingly, the following experiment was performed:

Four tarpon were placed in water 90% fresh and 10% salt. The average temperature was 21 degrees C. and the average oxygen content 2.69 cc. per liter. Attempts were made to induce rises in the tarpon by periodically

raising to the surface in a typical tarpon respiratory rise a carved wooden model. This model was 10 cm. long, painted silver, and was a reasonably accurate though rough duplication of a tarpon in general body form. It had no fins, eyes nor mouth and was manipulated by the observer by means of two strings tied at its opposite ends.

Many attempts were unsuccessful, as is to be expected if a tarpon does not respond imitatively even to another of its kind unless it has reached a respiratory threshold. However, over a period of 12 hours of observation there were 47 successful inductions of rises in one or more tarpon. The average time for such imitative rises by a tarpon following its last rise was 4.35 minutes. The lowest elapsed time was 1.50 minutes and the highest was 12:00 minutes.

RESULTS OF OBSERVATIONS ON POOL MATERIAL.

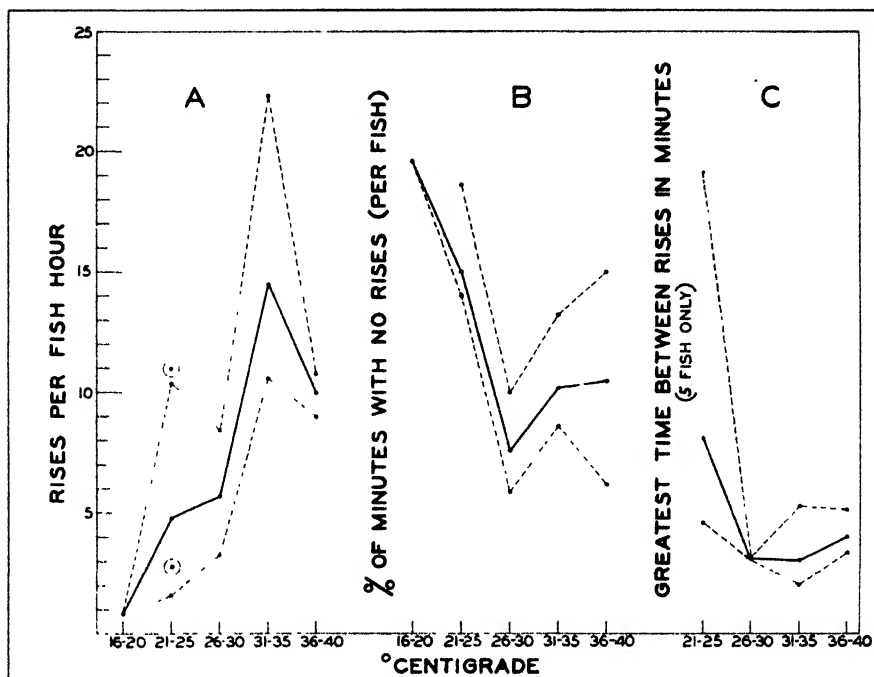
Data obtained in the field, together with analysis, are given in Tables VI to X. Under the conditions, estimates of locomotor activity were impossible, resulting in the confinement of these studies to the respiratory efforts of the tarpon. These fish were mostly of larger size than the aquarium material, the measurements being given in the tables.

"Imitation" in Respiratory Behavior.

The figures obtained on "imitative" rises in the two pools studied are in general agreement with those observed in small aquaria, differing only in the lesser extent of the imitation, Table IX. Since these pools were much larger and the fish able to retreat much further from each other and since the other centrifugal influences of the outdoors were present, this is exactly what should be expected. In accordance with this it is evident that there is a tendency for more fish to rise in groups in closer confinement or larger groups. This, again, would be expected, in that a greater opportunity of seeing a fish rise spontaneously is directly proportional to the number present in a given body of water.

Effect of Temperature on Respiratory Behavior.

In the laboratory the temperature differences were not great enough to give any measurable difference in the number of rises for respiratory purposes relative to thermal differences in the environment. With the large temperature differentials found in the outdoor pools, it was possible to establish a relationship between temperature and the amount of aerial respiratory activity encountered. Table VIII gives the rises per fish per hour tabulated according to the temperature scale in steps of 5 degrees Centigrade. Text-figure 1 illustrates some of the correlations between temperature and various elements in the respiratory rises of these practically wild fish. Table VIII and Graph "A" in this figure show a consistent increase in the number of rises per hour with an increasing temperature, from the lowest temperature to which the fish could be safely subjected without endangering their lives, 16° to 20° C., to a range of 31° to 35° C. Above this, 36° to 40°, which is close to their upper thermal limits, the respiratory rises actually fell off. At this temperature range there was, however, a marked difference in their activity. At the ranges lower than this one they swam about actively, which activity no doubt contributed to their respiratory needs and consistently added to their basic metabolic rate at any given temperature. At this higher level, however, they rested quietly in one place, evidently uncomfortable and making no more effort than was necessary to rise periodically to the surface. This is interpreted to mean that the inhibiting influence on their activity of this high temperature actually reduced their oxygen demand below that at the next lower temperature range where they were normally active.



Text-fig. 1.

Comparison of the respiratory behavior of small tarpon according to temperature in outdoor pools.

The solid line in this chart indicates the mean value as taken from Table VIII while the two dotted lines indicate the maximum and minimum values obtained.

Practical considerations made it impossible to take oxygen readings of the waters of these two pools at the time the observations were made. However, since both were supporting other fishes which are not able to respire air at the same time, they were clearly not near an anaerobic condition. Aquarium experiments in which oxygen content was measured showed that at a content of 2.5 cc. per liter, tarpon rose on the average of 11 times per hour in the 21° to 25° range. This is higher than any reading in the field, where we have good reason to suppose that the oxygen content was at all times considerably above that figure. In similar aquarium experiments at an oxygen content of 5.7 cc. per liter, the same fish rose on an average of 2.8 times per hour. This value is between the mean and minimum of the field observations, and there is reason to suppose that the field conditions more closely approached the latter figure than the former. These two values are indicated on Text-figure 1 by circled dots. It is noteworthy in this connection that the thermally lower parts of this chart were taken in New Jersey and the higher in Florida. Considering the differences in the dissolved salts in these two waters (see Table X), it is rather remarkable that the entire line is so consistent, tending to confirm the aquarium observations with regard to the apparent indifference that these fishes show to the toxicity of their environment.

The field observations were each made for stated periods and tabulated by minutes. Consequently there were always some whole minutes which were represented on the note sheet by blanks. If a similar graph, "B" in Text-figure 1, is plotted showing these minutes without rises, expressed as

percentage of an hour, against a temperature scale, a line is obtained approximately the inverse of that of "A." It is, however, clearly not its mirror image and has the advantage of showing certain features not evident in the former. It, among other things, takes into account the manner of the grouping of the rises and smooths out a simple count of the number in an hour, since it is a measure of arbitrary units (minutes during which the tarpon were "holding their breath." If the imitative efforts of the tarpon modified this need for air seriously, this line should not so closely agree with the first. For example, fish rising a minute or more apart, as compared with all working within one minute in approximate synchronization, would result in vastly different lines. It is notable in this connection that while the number of rises per hour in "A" shows greater consistency (spread between minimum and maximum) in the highest temperature range, in "B" there is a reverse effect, this range showing the greatest spread, indicating that while the fish are probably doing little more than answering physiological needs they are at the same time paying less attention to their fellows.

These data may be handled in still a third way. If the greatest elapsed time between rises in minutes and seconds be plotted against a temperature scale, we obtain a line showing still other tendencies. For practical reasons the figures on this graph are limited to observations concerning five fish. This figure "C" in Text-figure 1 has rather different characteristics and actually the solid line of means is less valuable for consideration than the dotted maximum and minimum, for reasons given below. The line showing the maximum time between rises recorded is a measure of how long the fish can "hold their breath" and actually gives an estimate of the physiological needs of the fish apart from its socialized imitative behavior. The minimum line on the other hand gives an estimation of how soon a fish will follow a fellow to the surface after already having filled his "lung." In other words, this line is more of an index of social attitude than of respiratory need. Thus the mean becomes a time of averages between physiological demand and social influence. It is notable in this connection that the greatest spread between "physiological need" and "sociability" is registered in the lowest temperature range measured. This is interpreted to mean that while tarpon can hold their breath a long time at this temperature, they are also at liberty to be fully social. The line of "maximums" drops sharply with increased temperature, as should be expected from what we have already seen in "A" and "B." The line of "minimums" remains relatively closer to a horizontal line, indicating that their attitude toward their fellows is much less influenced by temperature than is their need for oxygen. It is noteworthy that the time of their greatest sociability is also at the range of their greatest respiratory activity, 31° to 35° C.

A considerable amount of differential behavior was noted in these field observations which is not amenable to statistical treatment.

For example, the pool at the Palmetto Key laboratory showed marked variations in the physical environment from time to time. None of the figures in the calculations show any significant differences associated with these changes, although the observed behavior of the tarpon was distinctly different.

At times when the surface of the water was clear and mirror-like, the fishes generally took their air with a resounding gulp and considerable agitation of the water. The surface disturbance so made is shown in Plate I, Figure 1. The center of the major circle is where the head protruded and the lesser one, to the right, was caused by the tail. This is typical of the rises at such times.

At other times the surface was covered with a scum of green algae that at times formed into a complete blanket. During the processes of formation the rises were much less evident and usually made without any tail splash. Plate I, Figure 2, shows the conditions during the formation of

such an algal scum. A fish had just risen to the left of center. This represents about the maximum disturbance under such conditions.

Later when the scum completely covered the pool, the disturbance incident to rises was even less. The algal blanket was such that it entrained and held the exhaled air, which floated on the surface for some minutes as bright green bubbles. This condition is shown in Plate I, Figure 3. The various bubbles are almost entirely from tarpon exhalations. As the fish normally emit a bubble from each gill opening, these were frequently seen as paired bubbles. The two largest to the left of center are such a pair, from the most recent rise.

While some of these features are referable to the physical condition of the water, the impression was gained that the tarpon disliked coming in contact with the green scum any more than was necessary, avoiding the usual tarpon "roll" of clear water.

DISCUSSION.

Since differences in the locomotor behavior of fishes may be used as one kind of measure of their mental state or psychic attitude toward their fellows, the recent development of a simple method of estimating these differences has stimulated work along such lines. Up to the present all species used for this type of study have shown distinct differences in the amount of locomotion in association with various groupings, homotypic or heterotypic. The species used have been *Carassius auratus*, Schuett (1934), Escobar, Minahan & Shaw (1936), Shlaifer (1938, 1939, 1940) Breder & Nigrelli (1938); *Gambusia affinis*, Escobar, Minahan & Shaw (1936). All considered the extent of travel per unit of time. In addition, Breder & Nigrelli (1938) considered the configurational pattern in three dimensional space and found similar differentiable behavior.

With this as a background, it came somewhat as a surprise to find that the tarpon, a markedly aggregating form, gave no mathematically significant figures from its locomotor behavior when alone or in aggregations. If such is present, it is extremely feeble as compared with the species previously studied, as all studies have been based on a reasonably comparable amount of data. It thus appears that this method may or may not be useful merely on a basis of whether it "works." Evidently fishes are no more uniform from group to group in this regard than they are in others.

This, obviously, is not to say that tarpon are indifferent to one another, for even a most superficial examination will show their strong aggregating tendency. Very possibly the difficulty lies in their relative inactivity as compared, for example, to the goldfish or shiners. When in the presence of the latter they show a marked increase in travel. That this relative inactivity is not merely a condition imposed by close confinement is evident when it is considered that in the garden pool of clear water their behavior was closely similar to that of the small aquaria; i.e., at nearly all times they were quietly aggregated in a relatively compact group, spaced about as they were in the aquarium.

That the metabolic rate is not vastly different under various conditions of grouping is shown by the similarity of their rising to breathe under different groupings; it rises notably only in the presence of goldfish, which no doubt is a result of their greater muscular exertions incident to their increased activity in swimming. Thus we are obliged to leave this portion of the study with the conclusion that the method of estimating social attitude from a basis of locomotor activity is not useful in estimating the social attitude of tarpon, on a purely pragmatic basis.

Since tarpon will rise to breathe air for purely physiological reasons and will also imitate each other in this item of behavior, there are thus two elements involved. While the full separation of them would be exceed-

ingly difficult, it has been shown in the tables that there is a high degree of imitation involved.

Very low oxygen concentrations induce more rises per hour, as would be expected, but grouping and changes in volume seem to have little effect. An unknown variable that must be considered in this connection is the amount of air exchanged on any given gulp. Judging from the figures, however, this would seem to have scant bearing on the social part of this behavior. The work of Schlaifer (1939) on the oxygen consumption of the goldfish, in which he showed that the rate varied with the grouping, could only be used in the present species in a properly arranged metabolic chamber, since both aerial and aquatic respiration are involved. As evidenced by the social factors to be seen in the rising behavior, such a study should be expected to give similar results.

In all these observations a rise has been considered imitative only if made a second or less after the initial rise. Those of a larger time interval have been considered independent. The question arises as to how long such behavior can be considered imitative, or, in other words, what of the memory image and inhibiting influences that give delayed responses? It would seem that first the tarpon must be in a physiologically receptive state, *i.e.*, have not recently gulped air, for two gulps in rapid succession have never been noted. Thus, if a tarpon has partly used up its air supply it may respond with more or less immediateness on the sight of an individual rising to breathe in response to a purely physiological need.

SUMMARY.

1. The locomotor behavior of tarpon is not a useful index in estimating their homotypic group behavior, nor is the extent of their rising to the surface to breathe.
2. There is a marked tendency toward imitation in tarpon rising to breathe, which is of social rather than physiological significance. More or less crude models properly manipulated will induce rises to breathe.
3. Observations in the field, checked against those in small aquaria, agree as to respiratory behavior and indicate the validity of the use of small aquaria for such purposes.
4. Goldfish and shiners, which are more active, induce in tarpon a marked increase in both locomotor and respiratory activity, as do goldfish with which tarpon are in contact through vision alone.
5. Environmental changes including barometric, chemical (salt and fresh water) and capacity of aquaria, do not significantly change the locomotor or respiratory behavior of tarpon, but a large reduction in dissolved oxygen increases respiratory activity. Large temperature changes also result in the alteration of the respiratory activity.

TABLE I.
Effect of Grouping on the Locomotor and Respiratory Activity of Small Tarpon.

Exp. Cond.	I. In Isolation			II. In Group of Two			IV. In Group of Four		
	Mean Activity ³	Mean No. of Rises ⁴	Cm. per Rise	Mean Activity ⁵	Mean No. of Rises ⁴	Cm. per Rise	Mean Activity ⁵	Mean No. of Rises ⁴	Cm. per Rise
A ¹	480.0	2.9	165.5	524.0	2.8	187.1	433.6	2.5	173.4
B ²	418.4	2.6	160.9	312.0	2.3	135.6	473.6	3.0	157.8

Statistical Analysis in P-Values ³ .									
Exp. Cond.	I vs. II	I vs. IV	I vs. IV	II vs. IV	I A ⁶ vs. I B	II A vs. II B	IV A vs. IV B		
A	Activity	Rises	Activity	Rises	Activity	Rises	Activity	Rises	
	0.5570	None ⁷	0.4589	0.4823	0.0908	0.5525	0.5444	0.5255	
B	0.1292	0.5570	0.4765	0.4940	0.0100	0.1631	0.0007	0.4823	0.4472 0.4706

¹ Volume is 48 liters of sea water in a 50-liter aquarium.

² Volume is 48 liters of water, 90% fresh, 10% salt, in a 50-liter aquarium.

³ Expressed in centimeters traversed per fish per 15-minute period of observation. In this and subsequent tables all figures listed under mean activity and mean number of rises refer to the average for each individual in the particular experimental condition and in each group forty-eight 15-minute periods of observation were divided equally among the number of fishes present when these were tarpon grouped together.

⁴ Expressed in surface rises to gulp air per fish per 15-minute period of observation.

⁵ Upper limit of statistical significance is set at 0.05. This is three times the probable error. P = 0.01 indicates good significance, while a value of 0.100 or more indicates little significance.

⁶ Letter refers to the experimental condition.

⁷ Indicates no significance calculated, since means are almost identical.

TABLE II.
Effect of Isolation, Homotypic and Heterotypic Grouping on the Locomotor and Respiratory Activity of Small Tarpon¹.

Part A—Goldfish.											
I. In Isolation			II. In Homotypic Group of Two			IV. In Homotypic Group of Four			IVa. In Heterotypic Group of Four ²		
Mean Activity ³	Mean No. of Rises ⁴	Cm. per Rise	Mean Activity ³	Mean No. of Rises ⁴	Cm. per Rise	Mean Activity ³	Mean No. of Rises ⁴	Cm. per Rise	Mean Activity ³	Mean No. of Rises ⁴	Cm. per Rise
496.0	2.1	236.1	221.6	1.0	221.6	586.4	2.7	217.1	1753.6	6.9	254.1
Statistical Analysis in P-Values.											
I vs. II			I vs. IV			II vs. IV			IV vs. IVa		
Activity	Rises	Activity	Rises	Activity	Rises	Activity	Rises	Activity	Rises	Activity	Rises
0.0002	0.0036	0.1900	0.2476	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Part B—Shiners.											
V. In Homotypic Group ⁶			Va. In Heterotypic Group ⁷			Mean Activity of Non-test Tarpon in Homotypic Group ⁸			Mean Activity of Non-test Shiners in Heterotypic Group ⁹		
Exp. Cond. ⁵	Mean Activity ⁸	Mean No. of Rises ⁹	Cm. per Rise	Mean Activity	Mean No. of Rises	Cm. per Rise	Mean Activity of Non-test Tarpon in Homotypic Group ⁸	Mean Activity of Non-test Tarpon in Homotypic Group ⁸	Mean Activity of Non-test Shiners in Heterotypic Group ⁹	Mean Activity of Non-test Shiners in Heterotypic Group ⁹	Mean Activity of Non-test Shiners in Heterotypic Group ⁹
A	289.6	0.6	816.0	938.4	1.1	853.1	470.4	3360.2			
Statistical Significances.											
V vs. Va—Activity—0134			V vs. Va—Rises—.0374			Non-test Tarpon vs. Non-test Shiners—Activity—.0000					

Statistical Significances.

V vs. Va—Activity—.0134

V vs. Va—Rises—.0374

Non-test Tarpon vs. Non-test Shiners—Activity—.0000

¹ Volume is 48 liters of water, 90% fresh and 10% salt, in a 50-liter aquarium.

² Consists of experimental tarpon and three goldfish, *Carassius auratus* (Linnaeus).

³ See Footnote No. 3 of Table I.

⁴ Expressed in surface rises to gulp air per fish per 15-minute period of observation.

⁵ Volume is 48 liters of water, 100% fresh, in a 50-liter aquarium. Temperature is 74 degrees F. Average oxygen content—5.62 cc. per liter.

⁶ Experimental tarpon is grouped with three other tarpon

⁷ Experimental tarpon is grouped with three golden shiners, *Notemigonus crysoleucas* (Mitchill).

⁸ Expressed in centimeters traversed per fish per 15-minute period of observation. Figure given is the mean of forty-eight 15-minute periods.

⁹ Expressed in surface rises to gulp air per fish per 15-minute period of observation. Figure given is the mean of forty-eight 15-minute periods.

TABLE III.
Effect of Visual Contact with the Same and Other Species upon the Locomotor and Respiratory Activity of Isolated Small Tarpon¹.

I. In Total Isolation			IV. In Visual Contact with Three Tarpon			IVa. In Visual Contact with Three Goldfish		
Mean Activity ²	Mean No. of Rises ³	Cm. per Rise	Mean Activity ²	Mean No. of Rises ³	Cm. per Rise	Mean Activity ²	Mean No. of Rises ³	Cm. per Rise
555.2	3.1	179.1	510.4	3.7	137.9	944.8	5.3	178.2
Statistical Analysis in P-Values.								
I. vs. IV.			I. vs. IV. a			IV. vs. IV. a		
Activity	Rises		Activity	Rises		Activity	Rises	
0.5381	0.4300		0.0601	0.0048		0.0000	0.206	
Statistical Analysis of Cross-comparisons Between Tables IIA and Above in P-Values.								
I.(2) ⁴ vs. I.(3)			IV.(2) vs. IV.(3)			IVa.(2) vs. IVa.(3)		
Activity	Rises		Activity	Rises		Activity	Rises	
0.4246	0.0832		0.2476	0.5570		0.0000	0.0340	
The Locomotor Activity ⁵ of the Non-Test Animals In Tables IIA and Above.								
Three Goldfishes			Three Goldfishes			Three Tarpon of		
III. of IVa, Table II			IIIa. of IVa, Table III			IIIb. IV., Table III	Mean No. of Rises ⁶	Cm. per Rise
2647.2			2538.4			514.4	2.4	214.3

Additional P-Values.

III (Table III) vs. IIIa (Table III)—0.5570
 III (Table III) vs. IV (Table II A)—0.0000
 IIIb (Table III—rises) vs. IV (Table II A)—0.4823

¹ Volume is 48 liters of water, 99% fresh and 10% salt, in a 50-liter aquarium. Transparent glass divides the aquarium into two compartments of 24 liters each. Experimental tarpon is in one compartment and the non-test animals in the other.

² See Footnote No. 3 of Table I.

³ Expressed in surface rises to gulp air per fish per 15-minute period of observation. See Footnote No. 3 of Table I.

⁴ Arabic numeral refers to the number of the Table.

⁵ Expressed in centimeters traversed per fish per 15-minute period of observation. Figure given is mean of forty-eight 15-minute periods. Based on data obtained during the respective experiments.

⁶ Expressed in surface rises to gulp air per fish per 15-minute period of observation. Figure given is mean of forty-eight 15-minute periods.

TABLE IV.
Degree of Imitation in Respiratory Activity¹.

Fish Rises	A ²		B ³		C ⁴		A, B and C combined		%
	In Group of Two	No. of Rises	In Group of Two	No. of Rises	In Group of Two	No. of Rises	In Group of Two	No. of Rises	
Alone	40		40		66		146		63.2
With one Companion	48		15		22		85		36.8
Alone	38		13		52		103		30.7
With one Companion	37		21		39		97		29.0
With two Companions	31		9		44		84		25.1
With three Companions	11		1		39		51		15.2

Additional data.

Of 177 rises of isolated tarpon in IV of Table III, 23 were induced by the rises of the three tarpon with which it was in visual contact.

In 23 instances out of 218, the rises of the isolated tarpon in IV of Table III induced rises in the tarpon with which it was in visual contact.

¹ All observations taken on homotypic groups of tarpon.

² Data based on observations taken during the running of A of Table I.

³ Data based on observations taken during the running of B of Table I.

⁴ Data based on observations taken during the running of the experiments of Table II A.

TABLE VI.

Respiratory Activity in a Fresh-Water Pool in New Jersey¹.
(One-half Hour Observation Periods).

No. of rises of all fish to surface in groups of:

Date	Time	°C	No.										
			Fish	1	2	3	4	5	6	7	8	9	Total
6/8 ²	1:28	24	5	3	6	6	0	0	—	—	—	—	15
6/8 ²	2:04	24	5	6	10	6	4	0	—	—	—	—	26
6/9 ³	11:00	24	5	1	0	3	0	0	—	—	—	—	4
6/9 ³	11:45	24	5	5	0	0	0	0	—	—	—	—	5
6/9 ⁴	3:40	23	5	8	4	3	0	0	—	—	—	—	15
6/9 ⁴	4:16	23	5	3	2	3	0	0	—	—	—	—	8
7/14 ⁵	11:21	21	5	13	0	0	0	0	—	—	—	—	13
7/14 ⁵	11:51	21	5	10	0	0	0	0	—	—	—	—	10
7/20 ⁶	2:35	26	9	11	4	0	0	0	0	0	0	0	15
7/20 ⁶	3:05	26	9	16	4	3	0	0	0	0	0	0	23
8/25 ⁷	11:00	18	5	0	2	0	0	0	—	—	—	—	2

Calculations.

Minutes without rises
in percent⁸

Rises per fish hour	Fish rising in groups by percent of total:										Per fish
	1	2	3	4	5	6	7	8	9	All	
6.0	20	40	40	00	00	—	—	—	—	73	14.6
10.4	24	37	24	15	00	—	—	—	—	57	11.4
1.6	25	00	75	00	00	—	—	—	—	93	18.6
2.0	100	00	00	00	00	—	—	—	—	83	16.6
6.0	54	26	20	00	00	—	—	—	—	73	14.6
3.2	38	25	37	00	00	—	—	—	—	83	16.6
5.2	100	00	00	00	00	—	—	—	—	70	14.0
4.0	100	00	00	00	00	—	—	—	—	70	14.0
3.3	73	27	00	00	00	00	00	00	00	63	7.0
5.1	70	17	13	00	00	00	00	00	00	53	5.9
0.8	00	100	00	00	00	—	—	—	—	98	19.6

¹ Fish used in this experiment: 9.5, 12.5, 11.25, 10.25, 10.75 cm. in standard length, placed in pool June 7. Added July 19: 11.1, 10.0, 11.9 cm. in standard length. This pool, recently made of concrete, is fed from a pipeline running from a private home. Water lilies and some *Lebistes reticulatus*, together with an occasional volunteer *Rana catesbeiana*, make up the remaining fauna.

² Fish remaining in deepest part of pool in a small aggregation. Partly cloudy with a slight haze; light s-w breeze. Rain threatening.

³ Fair with light easterly breeze. Rain had fallen from 7:00 to 10:00 a.m.

⁴ Thunder with rain threatening. Hazy and overcast. A small trickle of fresh water entering pool. Rain began at 4:35 p.m.

⁵ Sun bright, water crystal clear. Fish active, swimming in a larger group than before, over an area of about 4 ft. in diameter.

⁶ Humid and partly overcast; hazy. Light drizzle at 2:40 p.m. Fish in n-w corner, rising very quietly. Fish near surface for most part.

⁷ Cloudy, chilly. Weather has been unseasonably cold for some time.

⁸ Based on initial data, not shown in first part of table.

TABLE VII.

Respiratory Activity in a Brackish Water Pool in Florida¹.
(One Hour Observation Periods).

Date	Time	°C	No. fish	Number of rises of all fish in groups of:					
				1	2	3	4	5	Total
6/23 ²	9:27	33.5	5	31	22	15	8	5	81
6/25 ³	9:42	30.5	5	29	8	6	0	0	43
6/26 ⁴	9:52	33.0	5	25	16	12	0	0	53
6/26 ⁵	4:52	36.5	5	25	16	12	0	0	53
6/29 ⁶	9:34	34.0	5	50	16	3	0	5	74
6/29 ⁷	3:31	39.0	5	34	6	3	4	0	47
6/30 ⁸	11:58	37.0	5	20	18	12	4	0	54
7/1 ⁹	9:25	33.5	5	13	12	9	4	5	43
7/2 ¹⁰	2:27	36.0	4	30	6	0	0	—	36
7/4 ¹¹	11:52	34.0	3	67	0	0	—	—	67

Calculations.

Rises per fish hour	Fish rising in groups by percentage of total:					Minutes without rises in percent ¹³	
	1	2	3	4	5	All	Per fish
16.2	38	28	18	10	06	43	8.6
8.6	67	19	14	00	00	50	10.0
10.6	47	30	23	00	00	46	9.2
10.6	47	30	23	00	00	51	10.2
14.8	68	22	04	00	06	31	6.2
9.4	72	13	06	09	00	50	10.0
10.8	37	33	22	08	00	53	10.6
8.6	30	28	21	09	12	66	13.2
Mean ¹²							
11.2	52	25	16	04	03	49	9.8
9.0	83	17	00	00	—	60	15.0
22.3	100	00	00	—	—	30	10.0

¹ This pool, actually an old alligator hole, which had been artificially enlarged two years previous, is connected with the sea by a cut channel and receives sea water only at the highest spring tides. This channel is choked with fallen palmetto leaves, effectively preventing the passage of even small fish. The pool is usually sufficiently fresh for the island fauna to use for drinking purposes. These include various birds, coons and gopher tortoises. See Table X for analysis of this water. *Gambusia*, *Mollienesia*, *Cyprinodon* and both fiddler and blue crabs make up the remainder of the aquatic fauna.

² Clear and sunny. Water turbid; reddish colored. The fish used in this experiment measured 48.89, 31.16, 33.02, 30.48, 29.21 cm in standard length. The first two were removed in the order listed and had been placed in pool March 26, 1939, not having been disturbed since then.

³ Sky overcast, distant thunder. Pool covered with scum of algae, forming bright green bubbles wherever tarpon rolled. Fishes rising very quietly.

⁴ Rain most of previous night. Green scum on pool much reduced. Water much clearer.

⁵ Clear, shadows of palmettos reaching pool. Algal scum forming again. Fish scattered out all over pool. Formerly in deepest part.

⁶ Light clouds passing over sun. Scum no longer green; grayish-brown. A little rain previous night. Tarpon rolling all over pool.

⁷ Clear. Surface of pool cleaner. Tarpon making vigorous splashes.

⁸ Clear. Surface still cleaner. Fish roll well but lazily.

⁹ Clear. Scum as day before.

¹⁰ Clear. Scum completely gone from pool. Day before fish had been caught and measured. One died. Rain in the morning. Fish rising in all parts of pool.

¹¹ Clear. Spring tides. Day before, after the observation period, salt water entered and as this observation was being made water was again running in. Some slight scum on water. Another fish died. Fish feeding vigorously all around edge. Rain previous night. Pool overflowing banks in places. Fish widely scattered.

¹² The preceding footnotes indicate why, with the changed conditions, the last two periods have been omitted from some of the calculations.

¹³ Based on initial data, not shown in first part of table.

TABLE VIII.

Temperature and Rises in Pools.

Calculations Based on Tables VI and VII.

Behavior	Temperature in 5° intervals centigrade				
	16-20	21-25	26-30	31-35	36-40
	0.8	6.0	3.3	16.2	10.6
		10.4	5.1	10.6	9.4
		1.6	8.6	14.8	10.8
Rises per fish hour		2.0		8.6	9.0
		6.0		22.3	
		3.2			
		5.2			
		4.0			
Mean	0.8	4.8	5.7	14.5	10.0
Maximum	0.8	10.4	9.6	22.3	10.8
Minimum	0.8	1.6	3.3	8.6	9.0
	19.6	14.6	7.0	8.6	10.2
		11.4	5.9	9.2	6.2
		18.6	10.0	10.0	10.6
		16.6		13.2	15.0
% minutes without rises, per fish		14.6		10.0	
		16.6			
		14.0			
		14.0			
		14.0			
Mean	19.6	15.0	7.6	10.2	10.5
Maximum	19.6	18.6	10.0	13.2	15.0
Minimum	19.6	14.0	5.9	8.6	6.2
		6:46	3:10	2:61	4:31
		4:57	3:16	2:40	4:18
Greatest unit of time between rises in minutes and seconds ¹		19:18	6:03	3:43	3:23
		8:33	6:05	3:22	5:14
		5:08		2:57	5:02
		8:18		2:05	3:41
		7:26		5:09	4:20
		5:07		5:34	4:01
				3:16	
				2:44	
Mean of all		8:07	4:09	3:43	4:04
Maximum		19:18	6:05	5:34	5:14
Minimum		4:57	3:10	2:05	3:23
Mean (5 fish only)		8:07	3:13	3:04	4:01
Maximum		19:18	3:16	5:34	5:14
Minimum		4:57	3:10	2:05	3:41

¹ In this tabulation, the hour periods of the brackish water pool have been divided in two and read as recorded. All entries refer to groups of five fish except those in italics. From left to right these groups are of 9, 3 and 4 fish respectively.

TABLE IX.

Comparison of "Imitation" in Various-sized Groups and in Various-sized Volumes of Water.

Number of fishes in groups Total time of observation (in hours)	Aquaria		N. J. Pool		Florida Pool		
	2	4	5	9	3	4	5
	36	36	4½	1	1	1	8
No. fish in group rising	No. of rising fish in percent						
1	63	31	58	72	100	83	52
2	37	29	16	22	00	17	25
3	—	25	24	06	00	00	16
4	—	15	02	00	—	00	04
5	—	—	00	00	—	—	03
6	—	—	—	00	—	—	—
7	—	—	—	00	—	—	—
8	—	—	—	00	—	—	—
9	—	—	—	00	—	—	—
	Aquaria		N. J. Pool		Florida Pool		
Area in sq. meters	0.196		15		115		
Volume H ₂ O in liters	48		4,300		70,000		
% of rises alone (weighted means)	47		61		60		
% of group rises (weighted means)	53		39		40		

TABLE X.

Chemical Analysis of Pools in New Jersey and Florida.

Date (1940)	Florida		New Jersey
	June 30	July 4	Aug. 28
Albuminoid ammonia (p.p.m. Nitrogen)	14.000	11.000	.200
Free Ammonia (p.p.m. Nitrogen)	21.000	15.000	.220
Nitrate (p.p.m. Nitrogen)	.25	.25	.25
Chlorine (p.p.m.)	17,400.	18,250.	3.6
Hardness (p.p.m. Calcium carbonate)	8,100	8,100	92
Alkalinity (p.p.m. Calcium carbonate)	106	116	78
PO ₄ (p.p.m.)	1.2	1.7	—
SO ₄ (p.p.m.)	1900	2010	16
Iron (p.p.m.)	.05	.10	.30
Turbidity	1	2	1
Color (p.p.m. Platinum)	220	200	10
Total solids (p.p.m.)	55430	46770	252

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EXPLANATION OF THE PLATES.

PLATE I.

Respiratory behavior of tarpon under varying conditions. See text for explanation.

Fig. 1. A typical rise through a clean water surface. July 4, 1940.

Fig. 2. A typical rise through an algae-covered surface to left of center. June 26, 1940.

Fig. 3. Two sets of paired respiratory bubbles left entrained on algae-covered surface in lower left. June 25, 1940.

PLATE II.

Fig. 4. Two tarpon rises at less than a second's interval. The first is represented by the rings of large diameter. Bubbles may be seen at its center from the fish which has already descended. The second, left of center, has not as yet started the Newton's ring formation. Drops are still falling from the splash formed as the fish broke the surface.



FIG 1



FIG 2

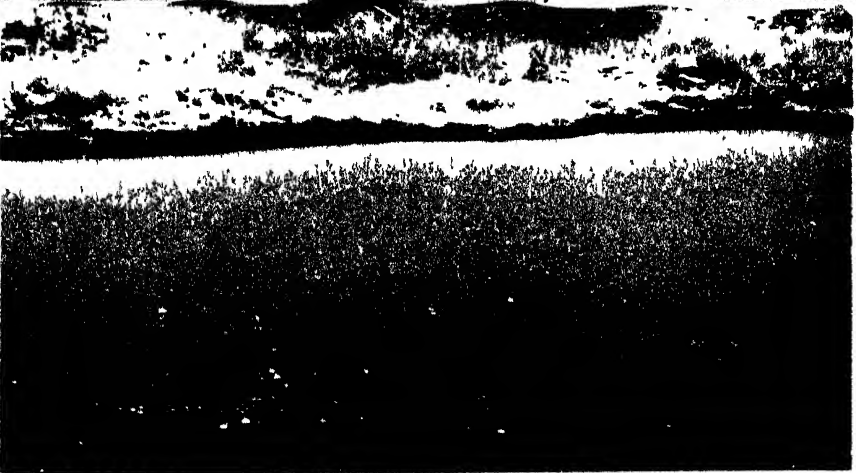


FIG 3



SOCIAL AND RESPIRATORY BEHAVIOR OF SMALL TARPON.

31.

New Observations on the Blood Group Factors in Simiidi and
Cercopithecidae*†

P. B. CANDELA, A. S. WIENER & L. J. GOSS.

(From the Department of Anatomy of the New York Medical College, the Serological Laboratory of the Office of the Chief Medical Examiner of the City of New York, and the New York Zoological Society).

This paper will serve to describe some new findings with regard to the blood group factors in a lowland gorilla (*G. gorilla*), and in monkeys belonging to two species of macaque (*M. mulatta* and *M. irus*).

Since these findings are a direct outgrowth of the discovery that certain conclusions previously reported by one of us (Candela, In press) were incorrect, it may be profitable to recount the successive stages in the investigation in a more or less chronological order.

It has been known for some time that the blood group factors A, B and O, whose presence or absence determine the four blood groups in man, are to be found also in the blood of the anthropoid apes. This fact was first suggested by the finding of group A in one chimpanzee, whose blood was examined by v. Dungern & Hirsfeld (1910-11), and established by the systematic study of Landsteiner & Miller (1925), which revealed that the blood of anthropoids contained also the agglutinin B, as well as A.

Since that time, the continuation of such investigations of the bloods of Simiidi and Hylobatidae has made it apparent that although all four groups are represented among the apes, each of the genera lacks at least one of the groups¹. Thus, the chimpanzee, on the strength of about 100 individuals, has only groups O and A, while the orang-utan and the gibbon have only groups A, B and AB. Until recently, the gorilla, represented by only four individuals, was reported to have only group A².

This distribution of the blood group factors seemed to imply that the B factor was not present in either of the two African anthropoids. Since the gorilla and the chimpanzee are generally conceded to resemble man more closely than do the Asiatic apes, the apparent lack of the B factor was anomalous, and stimulated various theories postulating its independent origin in the Asiatic apes, and in African man.

* Aided by a grant from the Committee on Scientific Research of the American Medical Association.

† A more extended report, including details of technique, will be published elsewhere. (Wiener, Candela & Goss, In preparation).

¹ This observation applies also to certain of the races of man, the most outstanding examples being the American Indians, the Polynesians and the Australian natives.

² Actually, as will be pointed out in a later paper (Wiener, Candela & Goss, In preparation), the results quoted on those four gorillas are entirely unreliable. The results reported by Landsteiner (1928) have been misquoted, since this investigator stated that he could not assign a definite group to the single gorilla which he examined. The results reported by Weinert on the remaining three gorillas have been shown by Dahr (1938) to be incorrect, since they are based on an invalid technique.

The importance of these questions to anthropology, and to the problem of human evolution, prompted one of us (C.) to attempt to determine the blood groups of the gorillas in the zoological parks of the United States, by means of tests upon their urines. Such tests are dependent upon the well-known fact that in man, at least, the group-specific substances responsible for the individual blood differences are present in water-soluble form in almost all the tissues and body secretions³.

The results of the tests on the urines of seven gorillas, three chimpanzees and one orang-utan have been detailed in a previous publication (Candela, 1940). It is sufficient to state that two mountain gorillas (*G. berengei*) were found to belong to group A, three lowland gorillas (*G. gorilla*) to group B, while two other lowland gorillas appeared from the reactions to belong to group AB, and were so reported. Actually, the diagnoses upon these last two were erroneous, for reasons which will presently appear (v.i.).

The dependability of the results obtained by testing ape urine was demonstrated by control tests on twenty human beings, whose groups were determined by independent tests on urine and blood, with complete correspondence. In addition, the blood of the orang-utan, and that of one of the chimpanzees were obtained and tested, and here also the results of the urine tests were confirmed by the reactions of the blood.

Another reason for accepting the urine reactions at their face value lay in the fact that those urines which gave A or B reactions, did so at the same dilution levels found to be suitable for testing human urines. As for the AB reactions, in which the samples removed both the α and the β agglutinins from the test sera, at least one of these reactions, namely that obtained with the urine of the orang-utan, was confirmed by tests upon his blood. It therefore seemed plausible that the two other AB reactions, obtained from the urines of the two gorillas, Janet and Susie, respectively, were equally valid.

TESTS UPON THE BLOOD OF THE GORILLA JANET.

An opportunity to check the accuracy of the urine tests on one of these two gorillas came with the transfer of Janet from the New York Zoological Society to the Laboratory of Physiology, The School of Medicine, Yale University, where certain studies were carried out under general anaesthesia.

Blood samples obtained at that time were examined by us, and the unexpected finding was made that the gorilla did not belong to group AB; in fact, it did not correspond exactly to any of the four human groups⁴, although it resembled most closely blood of group B.

The serum contained α agglutinins of moderate strength⁵, but no β agglutinins, and therefore corresponded with human group B serum. The erythrocytes were tested with anti-A and anti-B testing fluids, prepared from immune rabbit sera. No agglutination at all was obtained with the anti-A serum, and only very weak agglutination with the undiluted anti-B serum, although the latter gave distinct reactions with human B cells in dilutions as high as 1 to 32. Evidently, therefore, the gorilla blood contained an agglutininogen related to, but not identical with the human agglutininogen B. Thus, it is no longer accurate to state that the group factors in the blood of anthropoid apes are in all cases indistinguishable from those found in human blood.

Since the reactions of the gorilla's blood in anti-B serum were weak,

³ This statement applies only to "secretors." In "non-secretors," who constitute about 20% of white populations, the group-specific substances are absent from the secretions, or present only in traces.

⁴ In this respect, our results correspond with those of Landsteiner (footnote 2).

⁵ These were accompanied by relatively weak anti-human species agglutinins.

they might have been open to question, in the absence of additional supporting evidence. Accordingly, advantage was taken of the death of the gorilla to study the group-specific substances in its organs. Aqueous extracts of the submaxillary gland were found to inhibit human A (anti-B) serum in relatively high dilutions, but to have no effect on group B (anti-A) sera. This confirmed the grouping of the gorilla's blood as "B-like, α ".

The discrepancy between the results obtained from the tests upon the blood, and those previously obtained on the urine of this gorilla, necessitated the re-testing of the urine, not only of this gorilla, but also that of Susie, of the Cincinnati Zoological Society, who likewise had been thought to belong to group AB.

An interesting phenomenon was observed, in that while the undiluted or slightly diluted urines gave AB reactions, when they were diluted 1:6, they both gave B reactions⁶, inhibiting the β agglutinin but not the α (Table 1). Since the inhibition of the α (anti-A) agglutinin was thus much weaker than that of the anti-B, the former cannot with any degree of certainty be attributed to the presence of group-specific substance A⁷.

TABLE 1.

Results of the re-testing of specimens of urine from Janet and Susie, and three other apes.

Name	Species	Urine Dilution	Residual Agglutinins In: Group A serum	Group B serum
Janet	<i>G. gorilla</i>	1:3	—	—
Susie	<i>G. gorilla</i>	1:3	—	—
M'bongo	<i>G. berengei</i>	1:3	++++	—
Gargantua	<i>G. gorilla</i>	1:3	—	++++
Mike	<i>P. pygmaeus</i>	1:3	—	—
Janet	v.s.	1:6	—	++++
Susie	"	1:6	—	++++
M'bongo	"	1:6	++++	+++
Gargantua	"	1:6	+++	++++
Mike	"	1:6	++	++

Accordingly, it must be pointed out that the inaccuracy in reporting the groups of Janet and Susie as AB carries no implication as to the correctness of the conclusions arrived at with regard to the remaining nine apes in the series. This is particularly true since eight of these reacted as either group A or group B. With regard to the orang-utan, whose urine gave an AB reaction, his blood also gave an AB reaction, as has been already mentioned.

In summary, it may be said that, (1) The urines of the gorillas Janet and Susie had some adsorptive power for α as well as β , exceeding even the specific reactions of the urines of the remaining nine apes in the series and of the twenty human controls, but when tested at suitable dilution levels, they gave only distinct B reactions. (2) The blood cells obtained from Janet gave very weak reactions in anti-B serum, and none in anti-A serum, while the extract of the submaxillary gland gave a distinct B reaction. The serum of this gorilla contained α agglutinins but no β agglutinins. (3) Based on these new findings, it appears that of the seven gorillas tested to date, all five of the lowland species (*G. gorilla*) belong or are related to group B, while both of the mountain gorillas (*G. berengei*) belong or are related to group A.

⁶ But at this dilution, the urines of the other apes did not afford clear reactions, nor did the human urines (Table 1).

⁷ The phenomenon of the non-specific adsorption of both the α and the β agglutinins, with the production of false "AB" reactions, has been noted by one of us to occur also in the blood-grouping of human bones (Candela, In press).

TESTS UPON THE SECRETIONS AND BLOOD OF OLD-WORLD MONKEYS.

The interesting results obtained from the examination of the secretions, blood and tissues of the gorilla Janet suggested the performance of similar investigations upon monkeys.

The available information on the subject of the blood groups of monkeys is based on the examination of the blood alone. The data concerning old-world monkeys can be summarized as follows: (1) The erythrocytes of the Cercopithecidae are not agglutinated by anti-A or anti-B sera. (2) The sera of certain of these monkeys nevertheless contain anti-A or anti-B agglutinins. In the rhesus monkey (*M. mulatta*), anti-A agglutinins but not anti-B are regularly present in the serum; on the other hand, in *Cercopithecus*, anti-B is said to be present, but not anti-A. In baboons and other monkeys, one or the other agglutinin may be present, depending on the individual serum (Landsteiner, 1936; Thomsen & Kemp, 1930; Buchbinder, 1933).

From these observations, it has been concluded that the reciprocal or complementary arrangement of agglutinogens and agglutinins found in man and the anthropoid apes, does not hold true for monkeys. In man, and in the Simiidi and Hylobatidae, when the A factor is present alone in the blood cells, the serum contains agglutinin β , (or anti-B); when only the B factor is present, the serum contains α (anti-A); the absence of both factors from the blood cells is accompanied by the presence of both agglutinins in the serum; finally, when both factors A and B are present in the blood cells, neither iso-agglutinin is found in the serum.

The finding of a definite B factor in the salivary gland of the gorilla Janet, accompanied by distinct anti-A agglutinins in the serum, in the face of the extremely weak B reaction of the blood cells, suggested a new interpretation of the so-called blood group formula. It seemed possible that the lack of reciprocity between the reactions of the blood cells and those of the serum in monkeys might be reconciled by the results obtained from the examination of the tissues and secretions.

The first opportunity to test the validity of this idea arose when the death of a Java macaque (*M. irus*) made available for examination the sublingual gland, together with a block of tongue tissue⁸. The aqueous extract prepared from this material was found to inhibit, in high dilutions, human group A serum, but not to affect human group B serum, thus establishing the presence of group-specific substance B in the tissue extract.

Subsequently, the submaxillary gland and a sample of blood were obtained from a rhesus monkey (*M. mulatta*). The blood serum was found to contain a moderately strong α agglutinin, but the blood cells were not agglutinated by either anti-A or anti-B test sera. The extract prepared from the submaxillary gland inhibited group A serum, but not group B serum, thus yielding a definite B reaction, as anticipated from the presence of the α agglutinin but not the β agglutinin in the serum of the monkey.

In order to determine the presence of group-specific factors in the natural secretions of the macaques, specimens of urine from fifteen monkeys, identified only by numbers, were tested by one of us (C.). Four different kinds of reactions were obtained. In the first four samples, the tests all resulted in group B reactions. Of the remaining eleven, seven gave group A reactions. Three inhibited the A and B test sera equally; these could not be definitely interpreted, nor could a definite conclusion be reached upon the blood group of the monkey whose urine gave only a slight trace of inhibition of the α (anti-A) agglutinin.

The key list obtained after the completion of the tests disclosed the unexpected fact that, although all fifteen specimens of urine derived from macaques, the first four, which had given B reactions, had come from

⁸ Except as otherwise indicated, all the material used in this study was personally collected and prepared by one of the authors (G.).

rhesus monkeys (*M. mulatta*), while the remaining eleven, which had yielded seven group A reactions, had been obtained from Java macaques (*M. irus*).

Samples of saliva, obtained from the same fifteen monkeys by means of cotton swabs applied to the floor of the mouth, were tested independently by another of us (W.). These afforded confirmation of the validity of the four B and seven A reactions, and revealed that three of the doubtful individuals belonged to group AB. The fourth, which had yielded an extremely weak A reaction, gave an equally weak A reaction with the saliva. The decision as to group is much easier to make in tests upon the saliva, since this secretion gives specific reactions which are much stronger than those of the urine. For this reason, the failure of the last mentioned specimen (Table 2, number 11), to give a distinct reaction even in tests upon the saliva, suggested the possibility of group O.

The final step in the clarification of the blood group characteristics of this series of monkeys consisted in the testing of their bloods. The results of these tests were in harmony with previous findings obtained with the blood of old-world monkeys, in that the cells could not be agglutinated, while the sera contained group-specific agglutinins.

However, the identification of A-like and B-like factors in the tissues and secretions now made it evident that a reciprocal relation exists in monkeys between group-specific substance in the secretions, and the agglutinins in the serum, just as it does in man and the anthropoid apes between the agglutinogens in the blood cells and the agglutinins in the serum. Every monkey whose tissues or secretions contained the B factor alone, had the α , or anti-A, agglutinin in its blood serum; those in which the A factor alone was found, possessed the β , or anti-B agglutinin in their sera; those three which had both the A and the B factors in their secretions, lacked both iso-agglutinins from their sera, while the one monkey whose secretions suggested group O, had both agglutinins α and β in its serum.

FAMILIAL RELATIONSHIPS.

After the completion of the blood group studies upon the monkeys, the family relationships of sixteen of them were clarified by reference to the records of the New York Zoological Society. These sixteen monkeys fall into three families, and their mutual relationships, indicated in Table 2 by the letters x, y and z, may be summarized as follows:

Family x: Java macaques. *Father:* monkey number 00; *mother:* monkey number 7; *children:* monkeys numbers 6 and 15. In this family, the father gave a group B reaction, while the mother and two children reacted as group AB.

Family y: Rhesus monkeys. *Father:* monkey number 2; *mother:* monkey number 1; *children:* monkeys numbers 3 and 4. All members of this family gave group B reactions.

Family z: Java macaques. *Father:* monkey number 5; *mother:* not available; *children:* almost certain, number 8; certain: monkeys numbers 9, 10, 11, 12, 13, and 14. All members of this family gave A reactions, with the exception of number 11, which gave reactions corresponding to group O.

The laws governing the inheritance of the blood group factors in man are, in essence, two: (1) Neither the A nor the B factor appears in an offspring unless it is present in one or the other parent. (2) A parent belonging to group O cannot have a child of group AB, and a parent belonging to group AB cannot have a child of group O.

Although the numbers of monkeys herein reported are too small to permit definite conclusions, it can be said that in these three families of macaques, at least, no exceptions were found to the laws which govern the transmission of blood group factors in humans.

TABLE 2.
Results of tests upon the secretions, tissues and bloods of a gorilla and seventeen macaques.

Name or number and family	Taxonomic name	Source	Reaction from urine*	Reaction from tissues or saliva*	Reaction from erythrocytes*	Group-specific agglutinin in serum	Indicated group
"Janet"	<i>G. gorilla</i>	(NYZS) (Yale)	(AB') (B)	B	B-like	α	B
(x) 00. Java	<i>M. irus</i>	NYZS	not tested	B	not tested	not tested	B
0. Rhesus	<i>M. mulatta</i>	R.I.	not tested	B	'O'	α	B
(y) 1. "	"	NYZS	B	B	('O')†	(α)†	B
(y) 2. "	"	NYZS	B	B	('O')†	(α)†	B
(y) 3. "	"	NYZS	B	B	('O')†	(α)†	B
(y) 4. "	"	NYZS	B	B	('O')†	(α)†	B
(z) 5. Java	<i>M. irus</i>	NYZS	A	A	'O'	β	A
(x) 6. "	"	NYZS	O? AB?	AB	'O'	none	AB
(x) 7. "	"	NYZS	O? AB?	AB	not tested	none	AB
(z) 8. "	"	NYZS	A	A	'O'	β	A
(z) 9. "	"	NYZS	A	A	'O'	β	A
(z) 10. "	"	NYZS	A	A	'O'	α, β	A
(z) 11. "	"	NYZS	A? O?	O? A?	'O'	α, β	O?
(z) 12. "	"	NYZS	A	A	'O'	β	A
(z) 13. "	"	NYZS	A	A	'O'	β	A
(z) 14. "	"	NYZS	A	A	'O'	β	A
(x) 15. "	"	NYZS	O? AB?	AB	'O'	none	AB

Explanation of Symbols.

x, y, z: Family relationships.

NYZS: New York Zoological Society.

Yale: Laboratory of Physiology, Yale University.

R. I.: Rockefeller Institute for Medical Research.

*: Although the symbols A and B are used to represent the group-specific substances in the tissues and secretions, this is not intended to imply that these substances are completely identical with the corresponding factors in man.

(†) These bloods were not tested, since the findings on the blood of rhesus have been shown to be quite constant.

SUMMARY OF RESULTS.

1. A gorilla whose blood group had previously been diagnosed as AB from tests upon the urine, was found actually to belong or be related to group B, as a result of tests upon the blood and tissues. The apparent discrepancy was due to the reactivity of the urine for anti-A as well as anti-B sera, at dilution levels suitable for other specimens; in higher dilutions, the urine gave distinct B reactions. The reactions obtained by tests upon the blood serum and upon an extract of the gorilla's submaxillary gland closely paralleled those of a human group B individual. However, the erythrocytes were only feebly agglutinated by anti-B sera, indicated that the agglutinin present in the blood was similar to, but not identical with the human B agglutinin.

Of a total of seven gorillas tested, the revised results reveal that all five of the lowland gorillas (*G. gorilla*) belong or are related to group B, while both of the mountain gorillas (*G. berengeri*) belong or are related to group A.

2. Examination of the blood of one rhesus monkey (*M. mulatta*) confirmed the well-known fact that the cells of this primate are not agglutinated by anti-A and anti-B immune testing fluids, while the blood serum contains α (anti-A) agglutinin, but no β (anti-B) agglutinin.

3. The examination of the secretions or the tissues of five rhesus monkeys (including the one mentioned above) elicited the significant fact that a B-like factor, which had been thought to be entirely absent, is actually present, being demonstrable, not in the erythrocytes, but in the tissues and secretions.

4. The Java macaque (*M. irus*) was found to differ in its serology from rhesus, who belong exclusively to group B, in that reactions were obtained corresponding to groups A and AB, as well as group B. In seven of the twelve Java macaques examined the secretions gave a group A reaction, while the serum contained the β or anti-B agglutinin. The eighth individual was found to possess a B-like factor in his tissues; blood from this individual was not available for testing. Of the remaining four, three reacted as AB, in that their secretions inhibited both the α and the β agglutinins, while their sera did not contain either anti-A or anti-B agglutinins. The twelfth Java macaque gave very faint group A reactions from his urine and saliva, but was found to possess both the anti-A and anti-B agglutinins in his blood serum. Although these findings would seem to suggest a diagnosis of group O, further study is necessary for a definite decision.

The finding of an A-like factor in seven Java macaques is believed to be the first demonstration of the presence of the A factor in any monkey.

5. A correlation of the results of the blood group tests with the familial relationships of the three families of macaques discloses no exceptions to the rules which govern the heredity of the blood group factors in man.

CONCLUSIONS.

The results of our investigations upon the blood group characteristics of a lowland gorilla, five rhesus monkeys and twelve Java macaques permit certain conclusions to be drawn. These may have new implications for the general problem of the blood groups, and for the questions of the serological interrelationships of the primates.

The findings with respect to the secretions, tissues and blood of the gorilla provide an exception to the rule which holds for the other anthropoid apes, whose bloods gave reactions indistinguishable from those of man.

It is believed that our results have established for the first time the presence, in the tissues and secretions, of both A-like and B-like factors in the two varieties of macaques which were studied. These group-specific

factors are in each case accompanied by complementary agglutinins in the serum. Thus, a reciprocal arrangement of agglutinogen and agglutinin previously found only in man and the great apes, is now shown to hold true also in monkeys.

The apparent lack heretofore of such reciprocity was due to the fact that blood group investigations on monkeys have been confined to tests upon their bloods. The reactions obtainable from the secretions and tissues should constitute a valuable implement for future studies in the field of primate blood groups.

There is a suggestion in our results that certain blood group formulae may be distinctive for some of the species of anthropoids and monkeys. The large numbers of studies previously made on the rhesus monkey, re-interpreted in the light of our findings, justify the belief that all members of this species are related to group B. In the instance of the Java macaque, however, even the few herein reported suffice to show that they possess both the A and the B factors. Among gorillas, results from only seven individuals remain available at the present writing, since the four previously reported must now be discounted. These are insufficient to permit deductions; still it may be significant that all five of the lowland gorillas are now known to be similar to group B, and both individuals of the mountain species to group A.

It is significant that the only species of primates in which group O has been found are man and the chimpanzee^{9,10}. This suggests the possibility that the O property may have arisen by mutation from either the A or the B factor (probably the former), rather than the reverse mechanism, accepted by some writers, that A and B represent mutations from an original background of group O.

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⁹ The O property is not common even in the chimpanzee, since of the one hundred individuals tested, only twelve have been reported to be group O.

¹⁰ Although one of the Java macaques which we tested (number 11) appears to resemble a group O individual, some features of the results indicate caution in the acceptance of such a diagnosis. Further study of this monkey may reveal it to be a non-secretor, with atypical agglutinins (see footnote 3).

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32.

Muscle Dystrophy in Tree Kangaroos Associated with Feeding of Cod Liver Oil and Its Response to Alpha-Tocopherol.

LEONARD J. GOSS.

It is the purpose of this paper to report muscle dystrophy observed in tree kangaroos that conforms to that first produced artificially by Goettsch & Pappenheimer in Guinea pigs and rabbits maintained on a diet deficient in vitamin E. Similar lesions have been observed in rats by Evans & Lipschutz, who thought it to be of nervous origin. Olcott however definitely associated it with disease of skeletal muscles. A similar condition has also been seen in lambs and is known as "stiff lamb" disease.

The deleterious effect of oxidation on Vitamin E has long been known. It has also been shown that Vitamin E is affected by oxidation, when in association with such oxidizing agents as rancid oil. Madsen, McCay & Maynard showed that cotton seed oil containing a concentrate of Vitamins A and D in place of cod liver oil afforded a high degree of protection against muscular dystrophy in *Herbivora* and that one of the causative factors of the disease was in the saponifiable fraction of cod liver oil. McCay, Paul & Maynard prevented muscle lesions in Guinea pigs by using hydrogenated cod liver oil in place of natural cod liver oil. In dealing with encephalomalacia of chicks, Pappenheimer & Goettsch showed that hydrogenation greatly stabilizes fats that ordinarily readily become rancid. With these facts in mind we wish to report the occurrence of muscle dystrophy in tree kangaroos, its response to Alpha-Tocopherol treatment and its occurrence when oils were added to the diet.

In June, 1938, four tree kangaroos were received at the New York Zoological Park, indirectly from Australia. From June, 1938, until April 20, 1939, these animals were each maintained in the Park on an average daily ration of 2 small raw potatoes, 1 raw apple, $\frac{1}{4}$ head of lettuce, $\frac{1}{2}$ slice whole wheat bread, 1 medium-sized raw carrot and a small quantity of hay. The hay varied from alfalfa to mixed timothy and clover. On June 20, 1939, a fish oil mixture containing 3,400 units of Vitamin A and 660 units of Vitamin D per gram was added to the ration at the rate of 1 teaspoonful per animal per day. This oil mixture had been stored in a refrigerator since February, 1939, in a 29-gallon metal drum which was opened periodically to withdraw oil through a petcock.

On June 10, 1939, kangaroo No. 1 showed symptoms of stiffness, at which time the fish oil mixture was omitted from the balance of the usual ration. For a period of six weeks thereafter she was taken outdoors each day, weather permitting, and allowed to nibble on fresh green grass. Improvement was gradual and after six weeks of such treatment the symptoms of muscular stiffness had disappeared.

July 20, 1939, animal No. 2 developed symptoms of stiffness which became progressively worse and resulted in death in 2 days.

On September 22, 1939, animal No. 3 became stiff and died in 7 days.

The fish oil was removed from the diet when symptoms first appeared. All muscles, including the tongue, were severely affected.

On October 27, 1939, animal No. 4 became stiff and died in 6 days. All the dead animals showed extensive gross and microscopic lesions of muscle dystrophy, characterized by edema, opaqueness, a yellowish white coloration and in the later stages a gritty appearance. All voluntary muscles, including the tongue, were affected. The microscopic changes consisted of necrosis of the fibres, loss of fibrillar structure and calcium impregnation associated with varying stages of inflammatory reaction and myocytic regeneration.

Animal No. 1, which became stiff on June 10, 1939, was never put back on the fish oil diet but rather maintained on her original diet as outlined above. On January 19, 1940, she again developed typical symptoms of muscle dystrophy, this time without having had any oil. On January 20 the symptoms had become more marked and 25 milligrams of Alpha-Tocopherol were given by mouth. Three days later the symptoms had disappeared completely. This animal died July 3, 1940, of actinomycosis without having had a relapse since the administration of Alpha-Tocopherol. The second attack of muscular degeneration in the first animal affected is difficult to explain in the absence of oil in the diet. We must, however, assume that the regular ration bordered on deficiency in Vitamin E. This would account both for the occurrence of muscle degeneration in the animals when the oil was added to the diet and for the second attack in the one animal.

The results obtained when a fish oil mixture was included in the diet indicate that the oil itself has some action in producing muscular degeneration or that it inhibits the action of Vitamin E in preventing the disease.

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33.

Mortality Statistics for Specimens in the New York Aquarium, 1939.

ROSS F. NIGRELLI

Pathologist

(Plates I-III).

INTRODUCTION.

Approximately 1,600 specimens which died in the New York Aquarium during 1939 were examined to determine the cause of death. These are listed in Tables I to IV. A large number of specimens, especially fishes, which are being collected more or less continually for food and which also become part of the exhibition, are not included in this report. Such forms represent about 30% of the total population as given in the annual census. Also not included are those specimens which died immediately after their arrival; when large collections are made, from 20% to 30% usually survive long enough to become part of the Aquarium's exhibited population. However, in smaller, more selected collections, as much as 90% or more may survive. It should be remembered that aquatic species of animals, especially fishes, are difficult to handle and that those factors which tend to weaken them, *e.g.*, netting, transportation, change of water, also tend to lower their resistance to infective agents.

It is now pretty well established that host specificity among fishes and their parasites is the exception rather than the rule. One thing is certain—that under aquarium conditions such a relationship, if it exists at all, soon ceases to be, and may even take on an epidemic form, as in several cases reported here. In addition, it is known that infective agents tend to become more virulent in their effects when established on "abnormal" hosts.

Insofar as aquatic animals are concerned, the most virulent of the parasitic diseases are usually caused by external parasites, either protozoan or metazoan (flukes and copepods) living for the most part on the skin, eyes and gills.

It is very difficult in many instances to separate the primary from the secondary causes of death. For example, the primary cause which lowers the resistance of a given specimen may be a physical (such as fighting), chemical (changes in the water), or physiological (humoral or nutritional) one. If any of these adverse factors is sustained long enough, death follows; infective agents in such an instance may be but a secondary cause which only speeds up the demise.

The histo-pathology of the lesions produced by the various diseases has been, or will be, reported from time to time and therefore is not included in this report.

The writer wishes to express his thanks to Mr. James Atz for his assistance in the preparation of this paper.

CAUSES OF DEATH OF MARINE FISHES. TABLE I.

The great majority of the marine fishes were kept in a closed circulating system; some of the local species, however, were maintained in water pumped from the adjoining bay. This is the principal reason why more than half of the deaths of marine fishes resulted from infectious and parasitic diseases (Table V). The largest number of these was due to *Oodinium ocellatum*. This protozoan parasite was first observed in the New York Aquarium in 1935 (Nigrelli, 1936). At that time the fishes harboring it were indigenous to Sand Hook Bay. During 1939 the infection appeared on fishes collected from Florida, especially in those forms belonging to the families Lutianidae and Haemulidae. It is interesting to note that *Oodinium ocellatum* was first described from West Indian fishes kept in the London Aquarium. We have had an opportunity to study the organism from fishes of both regions and have come to the conclusion that the parasite is the same.

Among Sandy Hook Bay fishes a new protozoan parasite made its appearance in 1939. The life-history studies of this *Trichodina* were reported by Padnos (1939a and b). The parasite is found in large numbers on the gills of the common puffer and to a lesser extent on other species. The incidence of infection in puffers from Sandy Hook Bay is very high and studies indicate that these fish may be a potential source of infection of this and other parasitic diseases.

In previous years, *Epibdella melleni*, a monogenetic trematode, was the major cause of deaths of marine fishes, especially those belonging to the spiny-rayed group (Nigrelli & Breder, 1934). In 1939 most of the fishes infected belonged to the families Lutianidae, Haemulidae and Chaetodontidae. The latter includes some of the handsomest of all West Indian fishes, but is most susceptible to this trematode. Various techniques, however, are employed to keep this parasite under control, as well as other monogenetic trematodes of less importance, such as *Microcotyle* and *Diplectanus*. The life-history of *Microcotyle* and *Diplectanus* is being studied by Paul (1939).

One of the most interesting, but less devastating, of infectious diseases is lymphocystis (Nigrelli & Smith, 1939). This condition has been attributed to a virus causing tremendous hypertrophy of cells of connective tissue origin. The condition is usually limited to such cells in the skin and fins, but in more severe instances hypertrophied cells have been found in the spleen, gastro-intestinal tract and ovaries. Insofar as could be determined, no cellular disease of this type has been reported for man.

The largest number of mortalities attributed to parasitic and infectious diseases in marine fishes occurred during the months of July and August (Table VI), soon after the arrival of a large collection from Florida. As was stated in the Annual Report of the Zoological Society (Nigrelli, 1940a), the rate of mortality is far greater in recently arrived specimens.

One disease about which we as yet know nothing, although it was sporadic in occurrence, involves a peculiar ulceration of the skin around the mouth and the fins. Plate I, Figs. 1 & 2, shows a queen triggerfish with this affliction. The condition is first made evident by sores around the mouth, which continue to spread, resulting eventually in a sloughing off of tissues in this region; later the fins become involved, there being an intense inflammation of the skin at their bases. Biopsied and autopsied material failed to reveal the presence of a causative agent. The internal organs were normal to all appearances, but in most cases the optic nerves were inflamed and the optic muscles completely atrophied.

About 20% of the deaths of marine fishes resulted from non-infectious diseases, with a variety of causes and occurring throughout the year. Most of these diseases affected fishes which had been on exhibition for more than one year, and are of the type, with rare exceptions, that normally would be expected among any animal population of similar proportions and under

conditions of confinement. Some of these may be of parasitic origin, although no causative agents have been recovered; others may be entirely humoral or nutritional. The above remarks also hold for those non-infectious deaths among the other two groups of fishes.

Fishes are susceptible to relatively slight adverse changes in the physical, chemical and thermal conditions of their environment—some more so than others, but all to a certain degree. Therefore it is not surprising to find that a number of specimens succumbed as a result of such changes. The Elasmobranchs are particularly sensitive to changes in specific gravity, for example.

CAUSES OF DEATHS OF TEMPERATE FRESH-WATER FISHES. TABLE II.

A lower mortality rate occurred among the temperate fresh-water fishes. This may be attributed for the most part to the fact that these fishes were kept in an open circulation for most of the year. Any infection on one specimen was usually limited to that individual or perhaps its tank-mates. The present closed circulation was put into operation in October, 1939. However, the increase in mortality during the last two months of the year resulted from the influx of a large collection from Illinois, rather than the effects of the closed circulation (Table VI).

The largest number of deaths among this group was caused by *Ichthyophthirius multifiliis*, a well known and at times very virulent protozoan parasite. More than three-quarters of the deaths reported from this cause, however, occurred in one species of catfish. These fish were from one to two inches long and were confined in a single tank.

Saprolegnia only attacks fresh-water fishes which have been injured either mechanically or by parasites. Handling thus presents a constant hazard, since spores of this fungus are omnipresent.

Among helminth infections, some losses were attributed to worms belonging to the monogenetic trematode group referred to as Gyrodactyloides. These are skin and gill parasites, and a large number of species have been reported from fresh-water fishes. They constitute the most dreaded parasite in aquarium and hatchery management, often causing the loss of great numbers of specimens.

The disease referred to as Myxomata is very interesting and in all probability of parasitic origin. The general effects of any of the external parasites is to produce an irritation of the skin which results in an excessive production of mucus, the most important protective mechanism of fishes. Sometimes a translucent, soft growth remains, covering the whole fish or parts of it. This growth is microscopically seen to be composed of stellate-shaped connective tissue cells. One difference between this type of tumor and those of similar nature reported for man and other mammals is that the myxomata in the latter are richly supplied with capillaries.

The number of deaths recorded under Temperature is almost entirely accounted for by losses incurred among the trouts during the summer months. Mortalities recorded under Chemical Poisoning refer to a single species. A tank of muskellunge on open circulation was treated for a slight infection of *Ichthyophthirius* with a protein—silver salt, a compound continually used for such purposes. A chemical interaction between this chemical and the chlorine in the water at that time resulted in the formation of silver chloride, a highly toxic substance to fishes.

CAUSES OF DEATH OF FRESH-WATER TROPICAL FISHES. TABLE III.

These comprise some of the smallest of fishes, and it is consequently very difficult to perform adequate autopsy. For this reason, many deaths resulting from undetermined causes are listed here.

It is known among ecologists, aquarists and tropical fish fanciers that fishes living in small standing bodies of water alter the chemical content of their environment, apparently not only making it more suitable for themselves, but sometimes rendering it completely unsuitable for even rather closely related species. This has been called water conditioning. It is a very important factor in the maintenance of tropical fish, and a very large portion of the 23% of deaths recorded under Acclimatization resulted from these small fishes being unable to adjust themselves satisfactorily to a new aquatic environment. Just what this conditioning is has so far evaded successful analysis. Evidence indicates that some specific animal proteins may be involved.

Because these fishes are kept in completely separated tanks, the incidence of infectious disease is practically negligible.

CAUSES OF DEATH OF REPTILES. TABLE IV.

The largest number of deaths among reptiles was attributed to a general enteritis. Just what was producing this condition in the Aquarium specimens has not been determined. Since no parasitic infection was evident, it is altogether possible that the condition may be nutritional.

The most interesting of reptilian diseases so far studied is the one developed by large alligators, previously reported as fatty degeneration (Nigrelli, 1940a). Large deposits of encapsulated fatty substance may be found just beneath the skin; between layers of muscles (Plate III, Fig. 7) and possibly extending into muscular tissues; between the muscles and the peritoneum, lying just outside the latter; and also inside the peritoneal cavity. There are indications that organs may be involved, too. Animals suffering from this disease may lie in the pools for weeks, refusing all food. Just before death they may have one or more severe hemorrhages through the snout, mouth or anus.

CAUSES OF DEATH OF INVERTEBRATES. TABLE IV.

Although the great majority of invertebrates on exhibition were not autopsied, it is definitely known that these creatures are extremely sensitive to changes in the chemical composition of the water about them, Table V. Thus it is believed that the small sample autopsied does not at all exaggerate the importance of this factor as a cause of death.

TABLE I.

Causes of Mortality in Marine Fishes.

DISEASE	FISH	No. DEATHS
<i>Oodinium ocellatum</i> Brown 32.6% ¹	Holocentridae	
	<i>Holocentrus ascensionis</i> (Osbeck), Squirrelfish	5
	Cheilodipteridae	
	<i>Apogon maculatus</i> (Poey), Spotted Cardinal Fish	5
	Serranidae	
	<i>Centropristus striatus</i> (L.), Sea Bass	9
	<i>Epinephelus adscensionis</i> (Osbeck), Rock Hind	2 4
	<i>Epinephelus morio</i> (C. & V.), Red Grouper	1
	<i>Petrometopon cruentatus</i> (Lac.), Graysby	6

¹ Percentage of total number of recorded deaths.

<i>Rypticus saponaceus</i> (B. & S.), Soapfish	1
Lutianidae	
<i>Lutianus analis</i> (C. & V.), Muttonfish	2
<i>Lutianus apodus</i> (Walbaum), Schoolmaster	7
<i>Lutianus griseus</i> (L.), Gray Snapper	4
<i>Lutianus jocu</i> (B. & S.), Dog Snapper	2
<i>Lutianus synagris</i> (L.), Spot Snapper	9
<i>Ocyurus chrysurus</i> (Bloch), Yellowtail	17
Haemulidae	
<i>Anistoremus virginicus</i> (L.), Porkfish	40
<i>Haemulon albiun</i> C. & V., Margate Fish	1
<i>Haemulon flavolineatum</i> (Desmarest), Yellow Grunt	15
<i>Haemulon macrostomum</i> Gthr., Gray Grunt	5
<i>Haemulon plumieri</i> (Lac.), White Grunt	8
<i>Haemulon sciurus</i> (Shaw), Blue-striped Grunt	18
<i>Haemulon</i> sp., Iron Grunt	1
Sciaenidae	
<i>Eques acuminatus</i> (B. & S.), Cubbyu	4
<i>Menticirrhus saxatilis</i> (B. & S.), Northern Kingfish	6
Pomacentridae	
<i>Abudefduf saxatilis</i> (L.), Sergeant-major	2
<i>Dascyllus aruanus</i> (L.), Jesuite	8
Scaridae	
<i>Scarus caeruleus</i> (Bloch), Blue Parrotfish	10
Chaetodontidae	
<i>Angelichthys isabelita</i> Jordan & Ritter, Blue Angelfish	4
<i>Pomacanthus arcuatus</i> (L.), Black Angelfish	23
<i>Pomacanthus paru</i> (Bloch), French Angelfish	12
Acanthyridae	
<i>Acanthurus caeruleus</i> B. & S., Blue Tang	6
<i>Acanthurus hepatus</i> (L.), Doctorfish	2
Balistidae	
<i>Balistes vetula</i> L., Queen Triggerfish	4
Ostraciidae	
<i>Lactophrys trigonus</i> (L.), Common Trunkfish	9
Tetraodontidae	
<i>Spheroides maculatus</i> (B. & S.), Puffer	23
Diodontidae	
<i>Chilomycterus schoepfi</i> (Walbaum), Spiny Boxfish	17
<i>Didon hystrix</i> L., Porcupine Fish	2
Triglidae	
<i>Prionotus carolinus</i> (L.), Carolina Sea Robin	8
<i>Prionotus</i> sp., Blue-winged Sea Robin	2

<i>Trichodina</i> sp. 10.3%	Carangidae	
	<i>Caranx crysos</i> (Mitch.), Hard-tailed Jack	9
	Serranidae	
	<i>Centropristus striatus</i> (L.), Sea Bass	5
	<i>Roccus lineatus</i> (Bloch), Striped Bass	3
	Sparidae	
	<i>Stenotomus chrysops</i> (L.), Porgy	2
	Sciaenidae	
	<i>Menticirrhus saxatilis</i> (B. & S.) Northern Kingfish	7
	Tetraodontidae	
	<i>Spheroides maculatus</i> (B. & S.), Puffer	43
	Diodontidae	
	<i>Chilomycterus schoepfii</i> (Walbaum), Spiny Boxfish	12
<i>Epibdella melleni</i> MacCallum 17.9%	Triglidae	
	<i>Prionotus carolinus</i> (L.), Carolina Sea Robin	6
	<i>Prionotus evolans</i> (L.), Striped Sea Robin	8
	Holocentridae	
	<i>Holocentrus ascensionis</i> (Osbeck), Squirrelfish	2
	Carangidae	
	<i>Vomer setapinnis</i> (Mitch.), Moonfish	4
	Serranidae	
	<i>Cephalopholis fulvus</i> (L.), Coney	1
	<i>Dermatolepis marmoratus</i> Osburn & Mobray, Marbled Grouper	1
	<i>Epinephelus adscensionis</i> (Osbeck), Rock Hind	1
	<i>Mycteroperca interstitialis</i> (Poey), Princess Rockfish	2
	Lobotidae	
	<i>Lobotes surinamensis</i> (Bloch), Tripletail	1
	Lutianidae	
	<i>Lutianus analis</i> (C. & V.), Muttonfish	5
	<i>Lutianus apodus</i> (Walbaum), Schoolmaster	1
	<i>Lutianus griseus</i> (L.), Gray Snapper	1
	<i>Lutianus jocu</i> (B. & S.), Dog Snapper	1
	<i>Lutianus synagris</i> (L.), Spot Snapper	5
	<i>Ocyurus chrysurus</i> (Bloch), Yellowtail	1
	Haemulidae	
	<i>Anistoremus virginicus</i> (L.), Porkfish	26
	<i>Haemulon flavolineatum</i> (Demarest), Yellow Grunt	2
	<i>Haemulon macrostomum</i> Gthr., Gray Grunt	10
	<i>Haemulon plumieri</i> (Lac.), White Grunt	1
	<i>Haemulon sciurus</i> (Shaw), Blue-striped Grunt	3

	Sparidae	
	<i>Salema rhomboidalis</i> (L.), Salema	1
	Sciaenidae	
	<i>Pogonias cromis</i> (L.), Sea Drum	1
	Labridae	
	<i>Bodianus rufa</i> (L.), Spanish Hogfish	5
	<i>Julis pavo</i> (C. & V.), Swallow-tailed Wrasse	3
	<i>Lachnolaimus maximus</i> (Walbaum), Hogfish	16
	<i>Trechocopus scrofa</i> (C. & V.), Pink Wrasse	3
	Ephippidae	
	<i>Chaetodipterus faber</i> (Broussonet), Spadefish	5
	Chaetodontidae	
	<i>Angelichthys ciliaris</i> (L.), Queen Angelfish	4
	<i>Angelichthys isabelita</i> Jordan & Ritter, Blue Angelfish	29
	<i>Angelichthys townsendi</i> Nichols & Mowbray, Townsend's Angelfish	1
	<i>Chaetodon capistratus</i> L., Four-eyed Butterflyfish	5
	<i>Chaetodon collaris</i> Bloch, Lattice-work Fish	3
	<i>Chaetodon ocellatus</i> Bloch, Common Butterflyfish	3
	<i>Heniochus acuminatus</i> (L.), Long-finned Butterflyfish	1
	<i>Platax</i> sp., Sea Bat	1
	<i>Pomacanthus arcuatus</i> (L.), Black Angelfish	7
	Acanthyridae	
	<i>Acanthurus hepatus</i> (L.), Doctorfish	3
	Balistidae	
	<i>Balistes carolinensis</i> Gmelin, Common Triggerfish	2
	<i>Balistes vetula</i> L., Queen Triggerfish	1
	<i>Canthidermis sabaco</i> Poey, Ocean Triggerfish	4
<i>Microcotyle</i> sp. .76%	Chaetodontidae	
	<i>Chaetodon capistratus</i> L., Four-eyed Butterflyfish	2
	<i>Chaetodon collaris</i> Bloch, Lattice-work Fish	3
	<i>Chaetodon pictus</i> Forskål, Striped Butterflyfish	1
	<i>Holocanthus tricolor</i> (Bloch), Rock Beauty	1
<i>Diplectanus</i> sp. .54%	Pomacentridae	
	<i>Abudefduf saxatilis</i> (L.), Sergeant-major	1
	Tetraodontidae	
	<i>Tetraodon fluviatilis</i> (Buch.), Fresh-water Puffer	4

Lymphocystis .43%	Pomacentridae	
	<i>Amphiprion percula</i> (Lac.), Clownfish	1
	Chaetodontidae	
	<i>Angelichthys isabelita</i> Jordan & Ritter, Blue Angelfish	2
Ulceration of skin and fins .54%	Monacanthidae	
	<i>Ceratacanthus schoepfi</i> (Walbaum) Orange Filefish	1
	Kyphosidae	
	<i>Kyphosus sectatrix</i> (L.), Bermuda Chub	2
Trematode enteritis 1.30%	Ephippidae	
	<i>Chaetodipterus faber</i> (Broussonet), Spadefish	1
	Balistidae	
	<i>Balistes vetula</i> L., Queen Triggerfish	2
Cestode enteritis .65%	Holocentridae	
	<i>Holocentrus ascensionis</i> (Osbeck), Squirrelfish	2
	Carangidae	
	<i>Caranx hippos</i> (L.), Common Jack	1
	Serranidae	
	<i>Centropristus striatus</i> (L.), Sea Bass	1
	<i>Epinephelus morio</i> (C. & V.), Red Grouper	1
	<i>Mycteroperca bonaci</i> (Poey), Black Grouper	2
	<i>Roccus lineatus</i> (Bloch), Striped Bass	1
	Lutianidae	
	<i>Ocyurus chrysurus</i> (Bloch), Yellowtail	2
	Scorpaenidae	
	<i>Scorpaena madurensis</i> (C. & V.), Madeira Scorpionfish	2
Protozoan enteritis .11%	Galeidae	
	<i>Carcharhinus milberti</i> Müller & Henle, Ground Shark	2
	Acipenseridae	
	<i>Acipenser oxyrhynchus</i> Mitch., Common Sturgeon	2
	Carangidae	
	<i>Caranx crysos</i> (Mitch.), Hard-tailed Jack	1
Gastritis 2.49%	Triglidae	
	<i>Prionotus carolinus</i> (L.), Carolina Sea Robin	1
	Diodontidae	
	<i>Chilomycterus schoepfi</i> (Walbaum), Spiny Boxfish	1
	Ginglymostomidae	
	<i>Ginglymostoma cirratum</i> (Bonnaterre), Nurse Shark	1

	Acipenseridae	
	<i>Acipenser oxyrhynchus</i> Mitch., Common Sturgeon	4
	Serranidae	
	<i>Centropristus striatus</i> (L.), Sea Bass	2
	<i>Roccus lineatus</i> (Bloch), Striped Bass	1
	Sciaenidae	
	<i>Bairdella chrysura</i> (Lac.), Silver Perch	4
	<i>Leiostomus xanthurus</i> Lac., Spot	4
	<i>Micropogon undulatus</i> (L.), Croaker	1
	<i>Sciaenops ocellatus</i> (L.), Channel Bass	6
Biliary cirrhosis .22%	Siluridae	
	<i>Galeichthys felis</i> (L.), Sea Catfish	1
	Ephippidae	
	<i>Chaetodipterus faber</i> (Broussonet), Spadefish	1
Fatty degeneration of liver .22%	Serranidae	
	<i>Centropristus striatus</i> (L.), Sea Bass	2
Hepatitis, nematode infection .11%	Gadidae	
	<i>Urophycis chuss</i> (Walbaum), Squirrel Ling	1
Renal calculi .11%	Serranidae	
	<i>Mycteroperca bonaci</i> (Poey), Black Grouper	1
Kidney degeneration .54%	Serranidae	
	<i>Mycteroperca bonaci</i> (Poey), Black Grouper	1
	Ephippidae	
	<i>Chaetodipterus faber</i> (Broussonet), Spadefish	1
	Batrachoididae	
	<i>Opsanus tau</i> (L.), Toadfish	3
Ovarian degeneration .87%	Carchariidae	
	<i>Carcharias littoralis</i> (Mitch.), Sand Shark	1
	Aetobatidae	
	<i>Rhinoptera quadriloba</i> (Le S.), Cow-nosed Ray	1
	Acipenseridae	
	<i>Acipenser oxyrhynchus</i> Mitch., Common Sturgeon	3
	Serranidae	
	<i>Mycteroperca bonaci</i> (Poey), Black Grouper	3
Fatty degeneration, general .87%	Muraenidae	
	<i>Gymnothorax funebris</i> Ranzani, Green Moray	1

Fatty degeneration, general (continued)	Serranidae	
	<i>Epinephelus striatus</i> (Bloch), Nassau Grouper	3
	<i>Mycteroperca bonaci</i> (Poey), Black Grouper	2
	Lutianidae	
	<i>Lutianus griseus</i> (L.), Gray Snapper	2
<hr/>		
Swim-bladder disorder 2.27%	Gadidae	
	<i>Gadus callarias</i> L., Cod	21
<hr/>		
Gas aneurysm .54%	Sparidae	
	<i>Stenotomus chrysops</i> (L.), Porgy	1
	Sciaenidae	
	<i>Menticirrhus saxatilis</i> (B. & S.), Northern Kingfish	1
	Diodontidae	
	<i>Chilomycterus schoepfi</i> (Walbaum), Spiny Boxfish	2
	Triglidae	
	<i>Prionotus carolinus</i> (L.), Carolina Sea Robin	1
	<hr/>	
	Syngnathidae	
Malnutrition 4.65%	<i>Hippocampus hudsonius</i> ssp. De Kay, Seahorse	16
	<i>Hippocampus</i> sp., Long-nosed Seahorse	7
	Scaridae	
	<i>Pseudoscarus guacamaia</i> (Cuv.), Rainbow Parrotfish	8
	<i>Scarus caeruleus</i> (Bloch), Blue Parrotfish	9
	Monacanthidae	
	<i>Ceratacanthus schoepfi</i> (Walbaum), Orange Filefish	3
	<hr/>	
	Ephippidae	
	<i>Chaetodipterus faber</i> (Broussonet), Spadefish	2
Trauma of eyes .43%	Acanthyridae	
	<i>Acanthurus hepatus</i> (L.), Doctorfish	2
<hr/>		
Exophthalmos .32%	Serranidae	
	<i>Centropristus striatus</i> (L.), Sea Bass	3
<hr/>		
Tumor of thyroid 1.08%	Cyprinodontidae	
	<i>Cyprinodon variegatus</i> Lac., Sheepshead Minnow	10
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Senility? .97%	Siluridae	
	<i>Galeichthys felis</i> (L.), Sea Catfish	2
	Muraenidae	
	<i>Gymnothorax funebris</i> Ranzani, Green Moray	2
	Carangidae	
	<i>Trachinotus glaucus</i> (Bloch), Palometa	1

	Labridae	
	<i>Halichaeres radiatus</i> (L.), Pudding-wife	1
	<i>Thalassoma bifasciatum</i> (Bloch), Bluehead	1
	Cichlidae	
	<i>Tilapia mossambica</i> Peters	1
	Diodontidae	
	<i>Diodon hystrix</i> L., Porcupine Fish	1
Fractured skull .32%	Galeidae	
	<i>Mustelus canis</i> (Mitch.), Smooth Dogfish	2
	Sciaenidae	
	<i>Cynoscion regalis</i> (B. & S.), Weakfish	1
Eaten by tankmates .22%	Pomacentridae	
	<i>Pomacentrus albofasciatus</i> Schl., Striped Pomacentrus	2
Jumped from tank .43%	Mugilidae	
	<i>Mugil cephalus</i> L., Mullet	1
	Ostraciidae	
	<i>Ostracion cornutus</i> (L.), East Indian Cowfish	1
	Scorpaenidae	
	<i>Pterois volitans</i> (Bennett), Zebra Fish	2
Fighting .54%	Muraenidae	
	<i>Gymnothorax funebris</i> Ranzani, Green Moray	1
	<i>Gymnothorax moringa</i> (Cuv.), Spotted Moray	1
	Pomacentridae	
	<i>Eupomacentrus leucostictus</i> (Müller & Troschel), Beau Gregory	3
Handling 1.41%	Syngnathidae	
	<i>Hippocampus h. hudsonius</i> De Kay, Northern Seahorse	11
	Ephippidae	
	<i>Chaetodipterus faber</i> (Broussonet), Spadefish	2
Destroyed .54%	Holocentridae	
	<i>Holocentrus ascensionis</i> (Osbeck), Squirrelfish	5
Water chemistry 11.3%	Ginglymostomidae	
	<i>Ginglymostoma cirratum</i> (Bonnaterre), Nurse Shark	2
	Galeidae	
	<i>Carcharhinus milberti</i> Müller & Henle, Ground Shark	1
	<i>Mustelus canis</i> (Mitch.), Smooth Dogfish	8
	Carchariidae	
	<i>Carcharias littoralis</i> (Mitch.), Sand Shark	1

Water chemistry
(continued)

Water chemistry (continued)	Rajidae	
	<i>Raja</i> spp., Rays	10
	Dasyatidae	
	<i>Dasyatis centrura</i> (Mitch.), Stingray	5
	Aëtobatidae	
	<i>Rhinoptera quadriloba</i> (Le S.), Cow-nosed Ray	10
	Muraenidae	
	<i>Gymnothorax funebris</i> Ranzani, Green Moray	1
	Syngnathidae	
	<i>Hippocampus h. hudsonius</i> De Kay, Northern Seahorse	30
	Carangidae	
	<i>Seriola zonata</i> (Mitch.), Rudderfish	14
	Serranidae	
	<i>Centropristus striatus</i> (L.), Sea Bass	20
	<i>Roccus lineatus</i> (Bloch), Striped Bass	2
Unknown 4.44%	Megalopidae	
	<i>Tarpon atlanticus</i> (C. & V.), Tarpon	1
	Anguillidae	
	<i>Anguilla rostrata</i> (Le S.), Common Eel	1
	Mugilidae	
	<i>Mugil cephalus</i> L., Mullet	3
	Pleuronectidae	
	<i>Paralichthys dentatus</i> (L.), Fluke	3
	<i>Pseudopleuronectes americanus</i> (Walbaum), Winter Flounder	8
	Soleidae	
	<i>Achirus fasciatus</i> Lac., Hog Choker	3
	Cheilodipteridae	
	<i>Apogon maculatus</i> (Poey), Spotted Cardinal Fish	3
	Sciaenidae	
	<i>Eques acuminatus</i> (B. & S.), Cubbyu	4
	<i>Menticirrhus saxatilis</i> (B. & S.), Northern Kingfish	4
	Pomacentridae	
	<i>Amphiprion melanopus</i> Blkr., Anemone Fish	3
	Ostraciidae	
	<i>Lactophrys trigonus</i> (L.), Common Trunkfish	1
	Tetraodontidae	
	<i>Tetraodon</i> sp., Pacific Puffer	1
	Scorpaenidae	
	<i>Scorpaena madurensis</i> (C. & V.), Madeira Scorpion Fish	2
	Echeneididae	
	<i>Echeneis naucrates</i> L., Shark sucker	4

TABLE II.
Causes of Mortality in Temperate Fresh-water Fishes.

DISEASE	FISH	No. DEATHS
<i>Saprolegnia</i> sp. 6.66% ¹	Catostomidae <i>Ictiobus bubalis</i> (Raf.), Buffalo Fish <i>Moxostoma aureoleum</i> (Le S.), Redhorse Sucker	7 1
	Siluridae <i>Ameiurus nebulosus</i> (Le S.), Common Bullhead <i>Ictalurus punctatus</i> (Raf.), Channel Cat	5 1
<i>Ichthyophthirius multifiliis</i> Fouquet 45.3%	Salmonidae <i>Salmo irideus</i> Gibbons, Rainbow Trout	1
	Cyprinidae <i>Camptostoma anomalum</i> (Raf.), Stone- roller Minnow <i>Ericymba buccata</i> Cope, Silver-mouthed Minnow <i>Hybognathus</i> sp. <i>Pimephales promelas</i> Raf., Fat-headed Minnow <i>Semotilus atromaculatus</i> (Mitch.), Horned Chub	2 2 4 1 3
	Siluridae <i>Ictalurus punctatus</i> (Raf.), Channel Cat	80
	Centrarchidae <i>Ambloplites rupestris</i> (Raf.), Rock Bass <i>Micropterus dolomieu</i> Lac., Small- mouthed Bass	1 1
<i>Cyclochaeta domerqui</i> Wallengren .47%	Centrarchidae <i>Apomotis cyanellus</i> (Raf.), Green Sunfish	1
<i>Chilodon</i> sp. 1.43%	Centrarchidae <i>Helioperca macrochira</i> (Raf.), Blue- nosed Sunfish <i>Huro salmoides</i> (Lac.), Large-mouthed Bass <i>Micropterus dolomieu</i> Lac., Small- mouthed Bass	1 1 1
Protozoan, mixed infection 1.43%	Siluridae <i>Ameiurus nebulosus</i> (Le S.), Common Bullhead	1
	Centrarchidae <i>Micropterus dolomieu</i> Lac., Small- mouthed Bass	2
<i>Myxobolus</i> sp. .47%	Centrarchidae <i>Chaenobryttus gulosus</i> (Cuv.), Warmouth	1

¹ Percentage of total number of recorded deaths.

Gyrodactyloides (sp.?) 3.81%	Serranidae <i>Morone interrupta</i> Gill, Yellow Bass	8
<i>Argulus</i> sp. .47%	Lepisosteidae <i>Lepisosteus osseus</i> (L.), Long-nosed Gar	1
Cestode Enteritis .47%	Esocidae <i>Esox estor</i> Le S., Pike	1
Gastritis .47%	Amiidae <i>Amia calva</i> L., Bowfin	1
Malnutrition .95%	Catostomidae <i>Catostomus commersonii</i> (Lac.), Common sucker <i>Hypentelium nigricans</i> (Le S.), Hog Sucker	1 1
Edema 2.38%	Cyprinidae <i>Carassius auratus</i> (L.), Goldfish <i>Scardinius erythrophthalmus</i> (L.), Pearl Roach Centrarchidae <i>Micropterus dolomieu</i> Lac., Small-mouthed Bass	2 2 1
Ovarian degeneration 2.38%	Acipenseridae <i>Scaphirhynchus platyrhynchus</i> (Raf.), Shovel-nosed Sturgeon Salmonidae <i>Salvelinus fontinalis</i> (Mitch.), Brook Trout <i>Salvelinus fontinalis</i> (Mitch.), Albino Brook Trout Centrarchidae <i>Micropterus dolomieu</i> Lac., Small-mouthed Bass Percidae <i>Perca flavescens</i> (Mitch.), Yellow Perch	1 1 1 1
Myxomata? 6.19%	Salmonidae <i>Salmo fario</i> (Turton), Brown Trout <i>Salmo irideus</i> Gibbons, Rainbow Trout Centrarchidae <i>Helioperca macrochira</i> (Raf.), Blue-nosed Sunfish <i>Huro salmoides</i> (Lac.), Large-mouthed Bass <i>Micropterus dolomieu</i> Lac., Small-mouthed Bass	3 2 2 2 4
Epithelioma .47%	Salmonidae <i>Salvelinus fontinalis</i> (Mitch.), Albino Brook Trout	1
Scoliosis .47%	Acipenseridae <i>Scaphirhynchus platyrhynchus</i> (Raf.), Shovel-nosed Sturgeon	1

Lordosis .47%	Acipenseridae <i>Acipenser fulvescens</i> Raf., Lake Sturgeon	1
Senility? 1.43%	Amiidae <i>Amia calva</i> L., Bowfin	1
	Centrarchidae <i>Helioperca macrochira</i> (Raf.), Blue-nosed Sunfish	1
	<i>Lepomis auritus</i> (L.), Red-breasted Sunfish	1
Chemical poisoning 5.24%	Esocidae <i>Esox masquinongy</i> Mitch., Muskellunge	11
Destroyed .47%	Cyprinidae <i>Chrosomus erythrogaster</i> Raf., Red-bellied Dace	1
Water temperature 13.3%	Salmonidae <i>Salmo irideus</i> Gibbons, Rainbow Trout	5
	<i>Salvelinus fontinalis</i> (Mitch.), Brook Trout	23
Unknown 5.24%	Salmonidae <i>Salmo salar sebago</i> Girard, Land-locked Salmon	2
	Cyprinidae <i>Cyprinus carpio</i> L., Carp	1
	<i>Rhinichthys atratulus</i> (Hermann), Black-nosed Dace	1
	Centrarchidae <i>Eupomotis gibbosus</i> (L.), Pumpkin Seed	4
	<i>Pomoxis sparoides</i> (Lac.), Calico Bass	2
	Percidae <i>Perca flavescens</i> (Mitch.), Yellow Perch	1

TABLE III

Causes of Mortality in Tropical Fresh-water Fishes.

DISEASE	FISH	No. DEATHS
<i>Saprolegnia</i> sp. 1.81% ¹	Gymnotidae <i>Electrophorus electricus</i> (L.), Electric Eel	4
	Symbranchidae <i>Symbranchus marmoratus</i> Bloch	1
<i>Ichthyophthirius multifiliis</i> Fouquet 1.81%	Characinidae <i>Cheirodon piaba</i> Lütken	5
Stregeid .36%	Toxotidae <i>Toxotes jaculator</i> (Pallas), Archerfish	1
Ovarian cysts .36%	Cyprinodontidae <i>Rivulus harti</i> Boulenger	1

¹ Percentage of total number of recorded deaths.

Failure to deliver young 2.53%	Poeciliidae <i>Mollienisia sphenops</i> (C. & V.), Mollie <i>Xiphophorus hellerii</i> Heckel, Swordtail Swordtail X Platy Hybrid	2 2 3
Egg bound 3.25%	Characinidae <i>Copeina arnoldi</i> Regan, Splashing Salmlet <i>Epiplatys microlepis</i> Reinhardt, Glass Characin <i>Hyphessobrycon bifasciatus</i> Ellis, Yellow Tetra Gymnotidae <i>Eigenmannia virescens</i> (Val.), Glass Gymnotid <i>Gymnotus carapo</i> L., Banded Gymnotid Cyprinidae <i>Barbus conchoni</i> Ham-Buch., Rosy Barb <i>Barbus cummingi</i> Gthr. Cichlidae <i>Aequidens moronii</i> Steindachner <i>Geophagus surinamensis</i> (Bloch)	 1 1 1 1 1 1 1 1 1 1
Hepatic degeneration .36%	Anabantidae <i>Trichogaster trichopterus</i> (Pallas), Hairfin Gourami	1
Edema 2.17%	Cyprinidae <i>Barbus conchoni</i> Ham.-Buch., Rosy Barb Siluridae <i>Acanthodoras cataphractus</i> (L.) Anabantidae <i>Betta splendens</i> Regan, Siamese Fighting Fish <i>Macropodus cupanus</i> (C. & V.) <i>Macropodus opercularis</i> (L.), Forked- tail Paradise Fish Cichlidae <i>Aequidens latifrons</i> (Steindachner)	 1 1 1 1 1 1
Malnutrition 1.44%	Osteoglossidae <i>Osteoglossum bicirrhosum</i> Vandelli, Arowana Poeciliidae <i>Mollienisia velifera</i> Regan, Sailfin Mollie Cichlidae <i>Pterophyllum scalare</i> (C. & V.), Angel- fish	 1 1 2
Chemical poisoning, paint .72%	Gymnotidae <i>Sternopygus macrurus</i> (B. & S.)	2
Jumped from tank 1.08%	Polypteridae <i>Calamoichthys calabaricus</i> (Smith), Reedfish	1

	Characinidae	
	<i>Exodon paradoxus</i> Müller & Troschel	1
	Siluridae	
	<i>Clarias</i> sp.	1
Senility?	Polypteridae	
7.58%	<i>Calamoichthys calabaricus</i> (Smith), Reedfish	1
	Notopteridae	
	<i>Xenomystus nigri</i> Gthr., African Knife- fish	1
	Characinidae	
	<i>Hyphessobrycon flammeus</i> Myers, Flame Tetra	1
	<i>Hyphessobrycon heterorhabdus</i> (Ulrey)	1
	<i>Hyphessobrycon serpae</i> Durbin	1
	<i>Moenkausia pittieri</i> Eigenmann	1
	<i>Mylossoma duriventris</i> (Cuv.)	1
	<i>Nannaethiops unitaeniatus</i> Gthr.	1
	<i>Pristella riddlei</i> (Meek)	1
	Gymnotidae	
	<i>Gymnotus coatesi</i> LaMonte, Tiger Knifefish	1
	Cyprinidae	
	<i>Barbus lineatus</i> Duncker	2
	<i>Esomus malayensis</i> E. Ahl, Malayan Flying Barb	1
	<i>Rasbora trilineata</i> Steindachner, Three- lined Rasbora	1
	Aspidinidae	
	<i>Bunocephalus bicolor</i> Steindachner	1
	Siluridae	
	<i>Acanthodoras</i> sp.	1
	Poeciliidae	
	<i>Belonesox belizanus</i> Kner, Pike-killie	1
	Anabantidae	
	<i>Ctenops vittatus</i> (C. & V.), Croaking Gourami	1
	Ophiocephalidae	
	<i>Channa asiatica</i> (L.), Snake-head	1
	Nandidae	
	<i>Badis badis</i> (Ham.-Buch.)	1
	Cichlidae	
	<i>Etroplus suratensis</i> (Bloch)	1
Missing	Cyprinidae	
2.53%	<i>Rasbora trilineata</i> Steindachner, Three- lined Rasbora	1
	Cyprinodontidae	
	<i>Aphyosemion calliurum</i> (Boulenger), Lyretail	1
	Poeciliidae	
	<i>Belonesox belizanus</i> Kner, Pike-killie	2

Missing (continued)	Hemirhamphidae	
	<i>Dermogenys pusillus</i> van Hasselt, Fresh-water Halfbeak	1
	Anabantidae	
	<i>Helostoma temminckii</i> C. & V., Kissing Gourami	1
<hr/>	Cichlidae	
	<i>Crenicichla lepidota</i> Heckel	1
	<hr/>	
Destroyed 1.81%	Siluridae	
	<i>Acanthodoras</i> sp.	1
	Loricariidae	
<hr/>	<i>Loricaria</i> sp.	4
	<hr/>	
Water temperature 3.25%	Characinidae	
	<i>Creatochanes melanurus</i> (Bloch)	1
	Cyprinodontidae	
	<i>Fundulus chrysotus</i> Holbrook	1
	<i>Fundulus ocellaris</i> Jordan & Gilbert	1
	<i>Oryzias latipes</i> (Schl.), Medaka	1
	Cichlidae	
	<i>Cichlosoma severum</i> (Heckel), Deep-bodied cichlid	3
	<i>Herichthys cyanoguttatus</i> Baird and Girard	2
	<hr/>	
"Spoiled" water 4.70%	Dasyatidae	
	<i>Potamotrygon hystrix</i> (Müller & Troschel), Fresh-water Stingray	2
	Characinidae	
	<i>Nannaethiops unitaeniatus</i> Gthr.	2
	Cyprinidae	
	<i>Barbus semifasciatus</i> Gthr., Half-banded Barb	2
	Cyprinodontidae	
	<i>Rivulus harti</i> Boulenger	4
	Poeciliidae	
	<i>Micropoecilia branneri</i> Eigenmann	2
	Cichlidae	
	<i>Symphysodon discus</i> (Heckel), Disc Cichlid	1
	<hr/>	
Fighting 8.30%	Characinidae	
	<i>Copeina arnoldi</i> Regan, Splashing salmlet	1
	<i>Creatochanes melanurus</i> (Bloch)	1
	<i>Leporinus affinis</i> Gthr.	1
	<i>Leporinus fasciatus</i> (Bloch), Black-ringed Groundfish	1
	<i>Serrasalmus scapularis</i> Gthr.	1
	Gymnotidae	
	<i>Gymnotus carapo</i> L., Banded Gymnotid	1
	Cyprinodontidae	
	<i>Chriopeops goodei</i> (Jordan)	1
	<hr/>	

	<i>Epiplatys chaperi</i> (Sauvage), Chaper's	
	Panchax	3
	<i>Panchax lineatus</i> C. & V., Striped	
	Panchax	3
	Anabantidae	
	<i>Betta splendens</i> Regan, Siamese Fighting	
	Fish	3
	<i>Macropodus opercularis</i> (L.), Fork-tailed	
	Paradise Fish	3
	Cichlidae	
	<i>Cichlasoma cutteri</i> Fowler	1
	<i>Cichlasoma festivum</i> (Heckel), Painted	
	Cichlid	1
	<i>Hemichromis bimaculatus</i> Gill, Ruby	
	Jewel Fish	1
	<i>Hemichromis fasciatus</i> Peters	1
Acclimatization 23.1%	Osteoglossidae	
	<i>Osteoglossum bicirrhosum</i> Vandelli	2
	Mormyridae	
	<i>Mormyrus kannume</i> Forskål	1
	Characinidae	
	<i>Anoptichthys jordani</i> Hubbs & Innes,	
	Blind Characin	20
	<i>Carnegiella strigata</i> (Gthr.), Mottled	
	Hatchetfish	7
	<i>Chalceus macrolepidotus</i> Cuv.	1
	<i>Chilodus punctatus</i> Müller & Troschel,	
	Head-standing Fish	1
	<i>Copeina arnoldi</i> Regan, Splashing salmlet	3
	<i>Corynopoma riisei</i> Gill	4
	<i>Gasteropelecus sternicla</i> (L.), Hatchet-	
	fish	3
	<i>Hemigrammus rhodostomus</i> E. Ahl, Red-	
	mouthed Tetra	1
	<i>Pterodiscus laevis</i> , Eigenmann, Flying	
	Characin	2
	Cyprinidae	
	<i>Rasbora pauciperforata</i> Weber & de	
	Beaufort	3
	Callichthyidae	
	<i>Corydoras</i> sp.	1
	Cyprinodontidae	
	<i>Aphyosemion calliurum</i> (Boulenger),	
	Lyretail	2
	Atherinidae	
	<i>Telmatherina ladigesii</i> E. Ahl	8
	Cichlidae	
	<i>Cichlasoma cutteri</i> Fowler	1
	Gobiidae	
	<i>Bolcophthalmus viridus</i> Ham.-Buch.	4
Unknown 32.8%	Mormyridae	
	<i>Mormyrus kannume</i> Forskål	1

Unknown
(continued)

Pantodontidae

- Pantodon buchholzi* Peters, Fresh-water Butterflyfish 1

Characinidae

- Anostomus plicatus* Eigenmann 1
Carnegiella strigata (Gthr.), Mottled Hatchetfish 1
Chalcinus elongatus Gthr. 1
Chalcinus rotundatus (Schomburgk) 1
Epicyrthus microlepis Reinhardt, Glass Characin 2
Hemiodus gracilis Gthr. 1
Hemiodus quadrimaculatus Pellegrin 1
Hyphessobrycon innesi Hubbs, Neon Tetra 2
Myloplus schomburgkii (Jardine) 2
Poecilobrycon eques (Steindachner) 1
Poecilobrycon trifasciatus (Steindachner), Three-lined Pencilfish 2
Poecilobrycon unifasciatus (Steindachner), One-lined Pencilfish 1
Prochilodus insignis Schomburgk, Flag-tail 1

Cyprinidae

- Barbus conchoniui* Ham.-Buch., Rosy Barb 2
Barbus oligolepsis (Bleeker) 1
Barbus phutunio (Ham.-Buch.) 1
Barbus sp. 5
Danio malabaricus (Jerdon), Giant Danio 1
Notropis metallicus Jordan & Meek 3
Rasbora heteromorpha Duncker, Red Rasbora 1
Rasbora maculata Duncker 2

Cobitidae

- Botia* sp. 1

Siluridae

- Centromochlus aulopygius* Kner 1
Microglanis parahybae (Steindachner) 1

Callichthyidae

- Corydoras arcuatus* Ahl 1
Corydoras leopardus Myers
Corydoras melanisteus Regan 1

Loricariidae

- Loricaria parva* Boulenger 1
Plecostomus sp. 1

Cyprinodontidae

- Chriopeops goodei* (Jordan) 1
Panchax lineatus C. & V., Striped Panchax 1

Poeciliidae

- Belonesox belizanus* Kner, Pike-killie 1
Limia nigrofasciata Regan 1
Limia vittata (Guichenot) 1
Mollienisia latipinna Le S., Mudpusser 2
Phalloceros caudomaculatus (Hensel) 4
Platypoecilus maculatus Gthr., Platy 10
Quintana atrizona Hubbs 1

Hemirhamphidae	
<i>Dermogenys pusillus</i> van Hasselt, Fresh-water Halfbeak	1
Anabantidae	
<i>Colisa lalia</i> (Ham.-Buch.), Dwarf Gourami	2
<i>Ctenops vittatus</i> (C. & V.), Croaking Gourami	4
<i>Macropodus opercularis</i> (L.), Fork-tailed Paradise Fish	3
Nandidae	
<i>Badis badis</i> (Ham.-Buch.)	1
<i>Monocirrhus polyacanthus</i> Heckel, Leaf-fish	4
<i>Polycentrus schomburgkii</i> Müller and Troschel, Casarab	1
Centrarchidae	
<i>Elassoma evergladci</i> Jordan, Pigmy sunfish	2
Cichlidae	
<i>Apistogramma pertense</i> , (Haseman), Dwarf Cichlid	1
<i>Apistogramma</i> sp.	1
<i>Etroplus maculatus</i> (Bloch), Orange Chromide	2
<i>Geophagus jurupari</i> Heckel, Demon Fish	1
<i>Geophagus surinamensis</i> (Bloch)	1
<i>Tilapia zillii</i> Gervais	1
Toxotidae	
<i>Torotes jaculator</i> (Pallas), Archerfish	1

TABLE IV.

Causes of Deaths in Specimens Other Than Fishes.

DISEASE	AMPHIBIANS	No. DEATHS
Fungus	<i>Cryptobranchus alleganiensis</i> (Daudin), Hellbender	2
	<i>Necturus maculosus</i> (Raf.), Mudpuppy	5
	<i>Proteus anguinus</i> , Olm	2
Red-leg disease <i>Proteus hydrophilus</i> (Sanarelli)	<i>Pipa surinamensis</i> , Surinam Toad	1
Myxoma	<i>Necturus maculosus</i> (Raf.), Mudpuppy	2
REPTILES		
Fungus 6.1% ¹	<i>Alligator mississippiensis</i> (Daudin), American Alligator	5
	<i>Chelys fimbriata</i> , Matamata	1
Liver abcess from nematodes 1.0%	<i>Natrix s. sipedon</i> (L.), Common Water Snake	1
Liver degeneration 1.0%	Guatemalan Turtle	1

¹ Percentage of total number of recorded deaths.

Fatty degeneration 7.1%	<i>Alligator mississippiensis</i> (Daudin), American Alligator	7
Malnutrition 6.1%	<i>Caiman jacuare</i> (Daudin) <i>Caiman sclerops</i> (Schneider) <i>Gecko</i> sp.	1 4 1
Enteritis 56.5%	<i>Caretta caretta</i> (L.), Loggerhead Turtle <i>Chrysemys picta</i> (Schneider), Painted Turtle <i>Clemmys guttata</i> (Schneider), Spotted Turtle <i>Clemmys insculpta</i> (Le Conte), Wood Turtle <i>Graptemys p. pseudogeographica</i> (Gray), Mississippi Map Turtle <i>Podochemis expansa</i> , Amazon River Turtle <i>Pseudemys scripta troostii</i> (Holbrook), Cumberland Turtle <i>Pseudemys scripta</i> ssp., Yellow-bellied Terrapin <i>Terrapene carolina</i> (L.), Box turtle <i>Trionyx</i> sp. Chinese River Turtle	1 23 6 6 1 1 8 1 7 1 1
Floating trouble? 1.0%	<i>Caretta caretta</i> (L.), Loggerhead Turtle	1
Fighting 2.0%	<i>Caiman sclerops</i> (Schneider) <i>Caretta caretta</i> (L.), Loggerhead Turtle	1 1
Drowned 7.1%	<i>Alligator mississippiensis</i> (Daudin), American Alligator <i>Trionyx ferox</i> (Schneider), Southern Soft-shelled Turtle	6 1
Unknown 12.1%	<i>Caiman niger</i> Spix <i>Caretta caretta</i> (L.), Loggerhead Turtle <i>Caretta kempii</i> (Garman), Kemp's Turtle <i>Chelys fimbriata</i> , Matamoras <i>Emys blandingii</i> (Holbrook), Blanding's Turtle <i>Graptemys geographica</i> (Le S.), Map Turtle <i>Malaclemys centrata</i> (Latreille), Diamond-back Terrapin <i>Macrochelys temminckii</i> (Troost), Alligator Snapping Turtle <i>Podochemis expansa</i> , Amazon River Turtle <i>Terrapene carolina</i> (L.), Box Turtle <i>Trionyx</i> sp. East Indian Mud Turtle	1 1 1 1 1 1 1 1 1 1 1 1

BIRDS

Tuberculosis?	<i>Spheniscus demersus</i> (L.), Blackfoot Penguin	2
Fractured leg, Gangrene	<i>Spheniscus humboldti</i> Meyen, Humboldt's Penguin	1

MAMMAL		
Malnutrition	<i>Trichechus inunguis</i> Natterer, Amazon Manatee	1
INVERTEBRATES		
Larval trematodes on gills	<i>Scyllarides latus</i> , Flat Lobster	1
Fighting	<i>Octopus</i> sp.	3
Water chemistry	<i>Fasciolaria gigantea</i> Kiener, Giant Band Shell	1
	<i>Fasciolaria tulipa</i> L., Tulip Band Shell	1
	<i>Limulus polyphemus</i> (L.), Horseshoe Crab	10
	<i>Calappa flammea</i> (Herbst), Queen Crab	2
	<i>Libinia dubia</i> Milne-Edwards, Spider Crab	7
	<i>Menippe mercenaria</i> (Say), Stone Crab	2
	<i>Panulirus argus</i> (Latreille), Spiny Lobster	1
	<i>Petrochirus bahamensis</i> , Sea-soldier	1
	<i>Squilla empusa</i> , Mantis Shrimp	1
	<i>Oreaster reticulatus</i> , Giant Starfish	10
	<i>Sargartia leucolena</i> , White Anemone	35
Unknown	<i>Cambarus</i> sp., Fresh-water Crayfish	5
	<i>Homarus americanus</i> Milne-Edwards, Northern Lobster	2
	Papaloapan Fresh-water Crab	1

TABLE V.

Summary of Mortality Percentage by Causes.

Causes	Marine	Fresh-water temperate	Fresh-water tropical	Amphibians	Reptiles	Birds	Mammals	Invertebrates
Infectious disease	64.8	60.5	3.9	83.3	1.0	67	0	1.2
Non-infectious disease	19.5	21.0	32.2	16.7	86.9	33	100	3.6
Water conditions ¹	11.3	13.3	31.1	0	0	0	0	85.5
Unknown	4.4	5.2	32.8	0	12.1	0	0	9.7

¹ Includes density, temperature, pH. and chemical composition.

TABLE VI.
Summary of Mortality Percentage by Months.

	<i>Marine</i>	<i>Fresh-water temperate</i>	<i>Fresh-water tropical</i>	<i>Total</i>	<i>Amphibians</i>	<i>Reptiles</i>	<i>Birds</i>	<i>Mammals</i>	<i>Invertebrates</i>
January	2.7	0	7.6	3.4	8.3	3.0	0	0	2.4
February	4.6	2.9	5.4	4.5	0	5.1	33.3	0	1.2
March	4.3	0	12.3	5.2	0	11.1	0	0	0
April	5.1	1.0	8.7	5.2	8.3	6.1	0	0	3.6
May	7.2	6.7	15.5	8.8	8.3	21.2	33.3	0	1.2
June	8.4	3.3	5.8	7.1	0	5.1	0	0	1.2
July	35.5	16.2	16.6	28.9	0	12.1	0	0	7.2
August	12.4	3.3	6.6	9.9	0	6.1	0	100	30.1
September	6.7	2.9	7.6	6.2	16.7	10.1	0	0	9.6
October	5.6	4.3	4.3	5.2	16.7	3.0	0	0	13.2
November	4.1	25.7	5.4	7.6	0	5.1	0	0	18.1
December	3.5	33.8	4.3	8.1	41.7	12.1	33.3	0	12.1

TABLE VII.
Summary of Mortality Percentage of Fishes by Sex.

	<i>Marine</i>	<i>Fresh-water temperate</i>	<i>Fresh-water tropical</i>	<i>Total</i>
Male	27.9	14.8	23.5	25.1
Female	37.2	39.0	35.0	37.0
Immature	5.9	40.5	9.4	11.8
Undetermined	29.0	5.7	32.1	26.1

TABLE VIII.
Longevity of Specimens which Died During 1939.

<i>Longevity</i>	<i>% of 925 marine fishes</i>	<i>% of 210 fresh-water temperate fishes</i>	<i>% of 277 fresh-water tropical fishes</i>	<i>% average of all fishes</i>	<i>% of 12 amphibians</i>	<i>% of 99 reptiles</i>	<i>% of 3 birds</i>	<i>% of one mammal</i>	<i>% of 88 invertebrates</i>
Unknown	—	—	6.9	1.3	—	—	—	—	—
One month or less.....	55.5	27.6	22.0	44.8	0	9.1	33.3	100.	12.0
Two to twelve months.....	39.3	60.0	50.2	44.5	100.	87.9	0	0	88.0
More than one year.....	5.2	12.4	20.9	9.4	0	3.0	66.7	0	0

TABLE IX.

Fishes Over Two Years Old which Died During 1939.¹

MARINE

Ten Years

Gymnothorax funebris Ranzani, Green Moray

Seven Years

Tilapia mossambica Peters

Six Years

Ginglymostoma cirratum (Bonnaterre), Nurse Shark

Five Years

Trachinotus glaucus (Bloch), Palmoneta*Gymnothorax moringa* (Cuvier), Channel Bass*Mycteroperca bonaci* (Pocoy), Black Grouper

Four Years

Acipenser oxyrinchus Mitchill, Common Sturgeon*Galeichthys felis* (Linnaeus), Sea Catfish*Gymnothorax moringa* (Cuvier), Spotted Moray*Seriola zonata* (Mitchill), Rudder-fish*Pogonias cromis* (Linnaeus), Sea Drum*Halachaeres radiatus* (Linnaeus), Pudding-wife*Thalassoma bifasciatum* (Bloch), Blue-head

Three Years

Tarpon atlanticus (Cuvier & Valenciennes), Tarpon*Roccus lineatus* (Bloch), Striped Bass*Scatophagus argus* (Bleeker), Seat

Two Years

Epinephelus striatus (Bloch), Nassau Grouper*Rypticus saponaceus* (Bloch & Schneider), Soapfish*Dascyllus aruanus* (Linnaeus), Jesuite*Chaetodipterus faber* (Broussonet), Spade-fish*Balistes retula* Linnaeus, Queen Triggerfish*Diodon hystrix* Linnaeus, Porcupine Fish

TEMPERATE FRESH-WATER

Six Years

Lepisosteus osseus (Linnaeus), Long-nosed Gar*Amia calva* Linnaeus, Bowfin

Five Years

Acipenser fulvescens Rafinesque, Lake Sturgeon*Huro salmoides* (Lacépède), Large-mouthed Bass*Morone interrupta* Gill, Yellow Bass

Four Years

Scaphirhynchus platyrhynchus (Rafinesque), Shovel-nosed Sturgeon*Esox masquinongy* Mitchill, Muskellunge*Ambloplites rupestris* (Rafinesque), Rock Bass*Lepomis auritus* (Linnaeus), Red-breasted Sunfish*Helioperca macrochira* (Rafinesque), Blue-nosed Sunfish

Three Years

Scardinius erythrophthalmus (Linnaeus), Pearl Roach*Ameiurus nebulosus* (Le Sueur), Common Bullhead*Perca flavescens* (Mitchill), Yellow Perch

Two Years

Salvelinus fontinalis (Mitchill), Albino Brook Trout*Pomoxis sparoides* (Lacépède), Calico Bass

TROPICAL FRESH-WATER

Six and One-half Years

Channa asiatica (Linnaeus), Snake-head

Five Years

Hypheobrycon heterorhabdus (Ulrey)*Hypheobrycon serpa* Durbin*Pristella riddlei* (Meek)*Serrasalmus scapularis* Günther

Four Years

Moenkhausia pittieri Eigenmann*Gymnotus coatesi* LaMonte, Tiger Knifefish*Ctenopoma vittatus* (Cuvier & Valenciennes), Croaking Gourami*Aequidens moronei* Steindachner

Three Years

Calamoichthys calabaricus (Smith), Reedfish*Esomus malayensis* E. Ahl, Malayan Flying Barb*Rasbora trilineata* Steindachner, Three-lined Rasbora*Etroplus suratensis* (Bloch)

Two and One-half Years

Xenomystus nigri Günther, African Knifefish*Barbus lineatus* Duncker

Two Years

Mylossoma duriventris (Cuvier)*Cheirodon piaba* Lütken*Rasbora heteromorpha* Duncker, Red Rasbora*Rasbora maculata* Duncker*Bunocephalus bicolor* Steindachner*Acanthodoras* sp.*Centromochlus aulopygius* Kner*Microglanis parahybae* (Steindachner)*Badis badis* (Hamilton-Buchanan)*Cichlasoma festinum* (Heckel), Painted Cichlid*Herichthys cyanoguttatus* Baird & Girard*Symbranchus marmoratus* Bloch¹ Includes only oldest specimen of each species.

TABLE X.
Parasites and Hosts Observed in 1939.¹

Parasite	Host	Site of Infection
I. Protozoa		
A. Marine species		
1. <i>Protrichomonas</i> sp.	<i>Chilomycterus schoepfii</i> (Walbaum)	Intestine
2. <i>Oodinium ocellatum</i> Brown	Marine fishes	Gills
3. <i>Trichodina</i> sp.	Marine fishes	Gills
B. Fresh-water species		
4. <i>Cyclochaeta domerqui</i> Wallengren	Fresh-water fishes	Skin & gills
5. <i>Chilodon</i> sp.	Fresh-water fishes	Skin & gills
6. <i>Ichthyophthirius multifiliis</i> Fouquet	Fresh-water fishes	Skin & gills
7. <i>Henneguya ameiurensis</i> ² Nigrelli & Smith	<i>Ameiurus nebulosus</i> (Le Sueur)	Skin
8. <i>Myxobolus</i> sp.	<i>Chaenobryttus gulosus</i> (Cuvier)	Gills
II. Trematoda, monogenetic		
A. Marine species		
9. <i>Epibdella melleni</i> MacCallum	Marine fishes	Skin & eyes
10. <i>Microcotyle</i> sp.	Marine fishes	Gills
11. <i>Diplectanum</i> sp.	Marine fishes	Gills
12. <i>Gyrodactyloides</i> (Spp?)	<i>Fundulus heteroclitus</i> (Linnaeus)	Skin & gills
B. Fresh-water species		
13. <i>Gyrodactyloides</i> (Spp?)	Fresh-water fishes	Skin & gills
III. Trematoda, digenetic adults		
A. Marine species		
14. <i>Lintonium vibex</i> (Linton)	<i>Spheroides maculatus</i> (Bloch & Schneider)	Pharynx
15. <i>Bianium plicatum</i> (Linton)	<i>Spheroides maculatus</i> (Bloch & Schneider)	Intestine
16. <i>Probiotrema</i> sp.	<i>Amphotistius sabinus</i> (Le Sueur)	Body cavity
17. <i>Tubulovesicula madurensis</i> ³ Nigrelli	<i>Scorpaena madurensis</i> (Cuvier & Valenciennes)	Stomach
18. <i>Hemiuridae</i> (Spp?)	Marine fishes	Stomach
19. <i>Podocotyle atzi</i> Nigrelli ³	<i>Scorpaena madurensis</i> (Cuvier & Valenciennes)	Intestine
20. <i>Allocreadiidae</i> (Spp?)	Marine fishes	Intestine
21. <i>Nematobothrium</i> sp.	<i>Sarda sarda</i> (Bloch)	Gills
22. <i>Sterrhurus branchialis</i> Stunkard & Nigrelli	<i>Trichiurus lepturus</i> Linnaeus	Gills
B. Fresh-water species		
23. <i>Allacanthocheasmus varius</i> Vancleave	<i>Morone interrupta</i> Gill	Intestine
24. <i>Allacanthocheasmus artus</i> Vancleave & Mueller	<i>Morone interrupta</i> Gill	Intestine
25. <i>Neochasmus umbellus</i> Vancleave & Mueller	<i>Morone interrupta</i> Gill	Intestine
26. <i>Bucephalus pusillis</i> (Stafford)	<i>Stizostedion vitreum</i> (Mitchill)	Intestine
27. <i>Allocreadium</i> sp.	<i>Eupomotis gibbosus</i> (Linnaeus)	Intestine
28. <i>Crepidostomum</i> sp.	<i>Helioperca macrochira</i> (Rafinesque)	Intestine
29. <i>Amphistome</i> (Sp?)	<i>Trichechus manatus latirostris</i> (Harlan)	Caecum

¹ Including species and specimens not on exhibition at the N. Y. Aquarium.

² See Nigrelli & Smith, 1940

³ See Nigrelli, 1940b.

IV. Trematoda, digenetic larvae

A. Marine fishes

- | | | |
|---|----------------------------------|----------------------------|
| 30. <i>Cryptocotyle lingua</i>
(Creplin) | <i>Tautoga onitis</i> (Linnaeus) | Encysted on
skin & fins |
| 31. <i>Metacercaria</i> (Sp?) | <i>Scyllarides latus</i> | Encysted on
gills |

B. Fresh-water species

- | | | |
|--|--------------------|--------|
| 32. <i>Neascus vancleavei</i>
(Agersbord) | Fresh-water fishes | Organs |
| 33. <i>Clinostomum complanatum</i>
(Rudolphi) | Fresh-water fishes | Skin |

V. Cestoda, adults

A. Marine species

- | | | |
|--|---|-----------|
| 34. <i>Calliobothrium verticillatum</i> (Rudolphi) | <i>Mustelus canis</i> (Mitchill) | Intestine |
| 35. <i>Crossobothrium laciniatum</i> Linton | <i>Carcharias littoralis</i> (Mitchill) | Intestine |

B. Fresh-water species

- | | | |
|--|---|-----------|
| 36. <i>Proteocephalus</i> sp. | <i>Huro salmoides</i> (Lacépède) | Intestine |
| 37. <i>Proteocephalus pinguis</i>
LaRue | <i>Esor estor</i> Le Sueur | Intestine |
| 38. <i>Corallobothrium</i> sp. | <i>Ictalurus punctatus</i> (Rafinesque) | Intestine |
| 39. <i>Bothriocephalus cuspidatus</i> Cooper | <i>Perca flavescens</i> (Mitchill) | Intestine |

VI. Cestoda, larvae

A. Marine species

- | | | |
|--|------------------------------------|------------------------------|
| 40. <i>Otobothrium crenacolle</i> Linton | <i>Poronotus tricanthus</i> (Peck) | Encysted around
vertebrae |
| 41. Tetrarhynchid forms | Marine fishes | Intestine |
| 42. Tetrarhynchid forms | Groupers | Encysted in
body cavity |

B. Fresh-water species

- | | | |
|--|---|-----------|
| 43. <i>Ligula intestinalis</i> (Goeze) | <i>Hyborhynchus notatus</i>
(Rafinesque) | Intestine |
|--|---|-----------|

VII. Nematoda

A. Fresh-water species

- | | | |
|----------------------------|--------------------------------------|-----------|
| 44. <i>Cumallanus</i> sp. | Fresh-water fishes | Intestine |
| 45. <i>Spinitectis</i> sp. | <i>Micropterus dolomieu</i> Lacépède | Intestine |

VIII. Hirudinea

A. Marine species

- | | | |
|--|-----------------------------------|------|
| 46. <i>Branchellion ravenelli</i> ⁴
(Girard) | <i>Dasyatis hastatus</i> (De Kay) | Skin |
| 47. <i>Pontobdella muricata</i>
(Linnaeus) | <i>Sphyrna zygaena</i> (Linnaeus) | Skin |

B. Fresh-water species

- | | | |
|--|---------------------|------|
| 48. <i>Placobdella parasitica</i>
(Say) | Fresh-water turtles | Skin |
|--|---------------------|------|

IX. Copepoda

A. Marine species

- | | | |
|--|------------------------------------|-------|
| 49. <i>Sphyrion lumpi</i> (Krøyer) | <i>Sebastes marinus</i> (Linnaeus) | Body |
| 50. <i>Chondranchthopsis nodosus</i> (Muller) | <i>Sebastes marinus</i> (Linnaeus) | Gills |
| 51. <i>Penella instructa</i> Wilson | <i>Xiphias gladius</i> Linnaeus | Body |
| 52. <i>Ergasilidae</i> (Spp?) | Marine fishes | Gills |
| 53. <i>Pandarus bicolor</i> Leach | <i>Mustelus canis</i> (Mitchill) | Skin |
| 54. <i>Lernaeenicus radiatus</i>
(Le Sueur) | <i>Menidia menidia</i> (Linnaeus) | Body |

⁴ See Meyer, 1939.

B. Fresh-water species

55. <i>Lernae</i> sp.	<i>Carassius auratus</i> (Linnaeus)	Body
56. <i>Argulus</i> spp.	Fresh-water fishes	Skin
57. <i>Ergasilus</i> sp.	Fresh-water fishes	Gills

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EXPLANATION OF THE PLATES.

All photographs by S. C. Dunton of the New York Aquarium.

- Figs. 1 and 2. Queen triggerfish, showing peculiar ulceration of the skin around the mouth and fins. The causative agent is unknown.
- Fig. 3. Edematous condition in pearl roach. A general anasarca was present and the kidneys were completely degenerated.
- Fig. 4. Viscera of small-mouthed bass, showing ovarian degeneration. This condition results from the failure to spawn and to resorb the eggs.
- Fig. 5. Portion of intestine of pike with heavy infestation of *Proteocephalus pinguis*. This infection was acquired in the wild state, since the fish lived but two months in captivity. The entire intestine was practically filled with these cestodes. Note the severe hemorrhage produced.
- Fig. 6. Intestine of blue-nosed sunfish with hemorrhagic islands caused by intestinal flukes. Not included in Table II.
- Fig. 7. Transverse section of alligator tail showing fatty degeneration. Large fat masses have pushed aside the muscles. Within these masses may be seen numbers of dark areas, consisting of hard, granular, yellowish material.

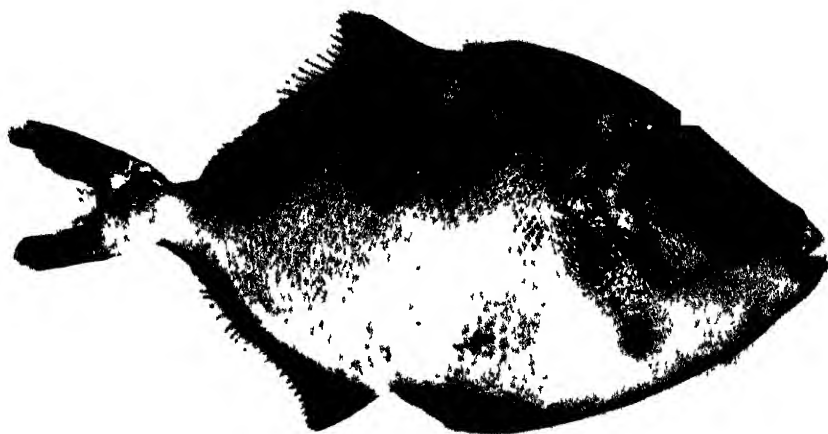


FIG. 1



FIG. 2

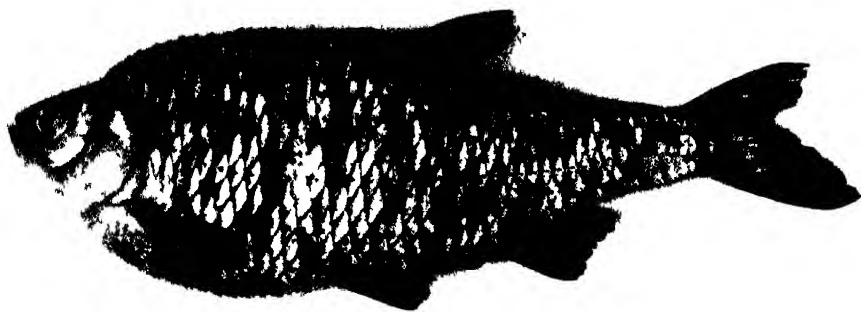


FIG. 3



FIG 4



FIG 5

MORTALITY STATISTICS FOR ANIMALS IN THE NEW YORK AQUARIUM 1939

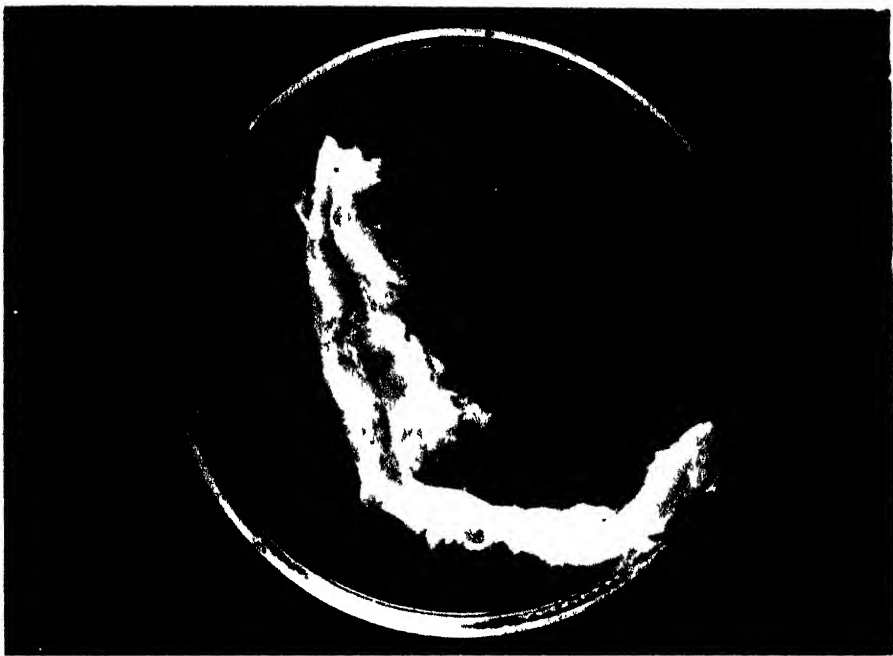


FIG 6

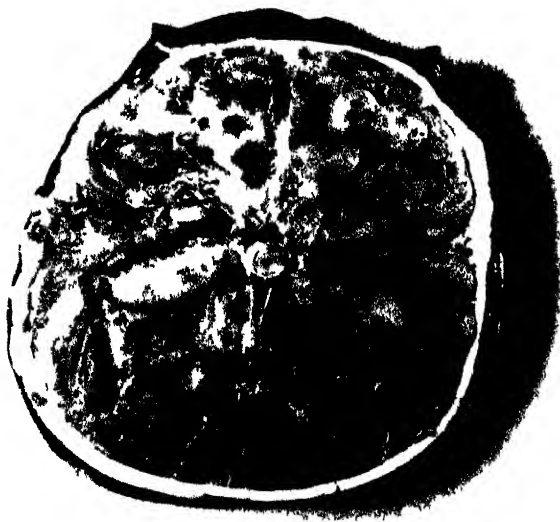


FIG 7

34.

A Comparison of Some Electrical and Anatomical Characteristics of the Electric Eel, *Electrophorus electricus* (Linnaeus).

R. T. COX

*Department of Physics, New York University, and Biological Laboratory,
Long Island Biological Association;*W. A. ROSENBLITH¹*Biological Laboratory, Long Island Biological Association;*

JANICE A. CUTLER

Washington Square College, New York University;

R. S. MATHEWS & C. W. COATES

New York Aquarium.

(Text-figures 1-7).

In a previous paper² it has been shown that the major and minor electrical discharges of the electric eel, *Electrophorus electricus* (Linnaeus), are produced respectively by the large organs and the organs of Sachs. It has also been shown³ that the current produced in a conductor joining two points along an electric organ could be approximately accounted for by ascribing to the segment of the organ between the two points a constant electromotive force and a variable internal resistance and considering it shunted by a constant leakage resistance which may be attributed to the adjacent tissue. Except during the discharge the internal resistance of the segment is assumed to be so much higher than the leakage resistance that the potential difference is negligible between different points along the organ. The discharge is attributed to a transient drop in the internal resistance, allowing the electromotive force to produce a current.

Let R denote the internal resistance of a segment of the organ at the peak of the discharge, when the resistance is at its minimum. Let E denote the electromotive force of the segment and let r denote the leakage resistance, of the adjacent tissue. Let R' denote the resistance of a conductor connected between electrodes in contact with the fish at the ends of the segment and let V denote the potential difference between these electrodes at the peak of the discharge. Then these quantities may be shown to be related by an equation, which may for the present purpose conveniently be written in the form

$$\frac{E}{V} = \frac{R}{R'} + \frac{r+R}{r} \quad (1)$$

¹ Now at Department of Physics, University of California at Los Angeles.

² Coates, C. W., R. T. Cox, & L. P. Granath. The Electric Discharge of the Electric Eel, *Electrophorus electricus* (Linnaeus). *Zoologica*, Vol. XXII (Part 1), No. 1, April 5, 1937.

³ Cox, R. T., & C. W. Coates. Electrical Characteristics of the Electric Tissue of the Electric Eel, *Electrophorus electricus* (Linnaeus). *Zoologica*, Vol. XXIII (Part 2), No. 8, July 14, 1938.

If R' is varied in this equation, V varies with it in such a way that for every change in $1/R'$ there is a proportional change in $1/V$. Consequently the graph of $1/V$ plotted against $1/R'$ will be a straight line. In Text-fig. 1 are plotted measurements of peak voltages obtained with various external resistances joined to electrodes 10 cm. apart on the large organ of an electric eel 103 cm. long. The sets of points indicated by different signs show sets of observations made at several different times. It will be seen that the points fall near to a straight line. (It should perhaps be pointed out that this does not prove the hypothesis of a variable internal resistance and constant electromotive force. This must be based upon other evidence discussed in the previous paper. The equation just given would still be valid if the internal resistance were constant and the electromotive force variable).

From the equation (1), when $1/R'$ is zero, then

$$V = \frac{E r}{r + R} \quad (2)$$

This corresponds to the case in which there is no external conductor between the electrodes. If the leakage resistance r is much greater than the internal resistance R , the observed peak voltage V will be nearly equal to the electromotive force E .

If, in the equation (1), $1/V$ is set equal to zero, then

$$\frac{1}{R'} = -\left(\frac{1}{r} + \frac{1}{R}\right) \quad (3)$$

Since negative values of the resistances are impossible, this case corresponds to no actual observation. But the line determined by the actual observations may nevertheless be extended, as in Text-fig. 1, to meet the axis of $1/R'$ and the intercept may be noted to determine $1/r + 1/R$. If the leakage resistance r is otherwise known, this last result makes it possible to determine R , the internal resistance of the segment of the electric organ. With both these resistances known, the intercept on the axis of $1/R'$ may be used to determine the electromotive force E .

With the electric eel already mentioned the leakage resistance r was measured between electrodes 10 cm. apart along the portion of the body containing the electric organs. The measurement was made by observing the current passing through the body of the eel between the electrodes when a measured potential difference was applied to them. The peak voltages produced between the same electrodes in the same positions on the fish with various resistances connecting them were measured in both the major and minor discharge by means of a cathode-ray oscillograph. The electromotive force and the internal resistance of each segment 10 cm. long down the length of the organs were determined as already explained and as illustrated by Text-fig. 1.

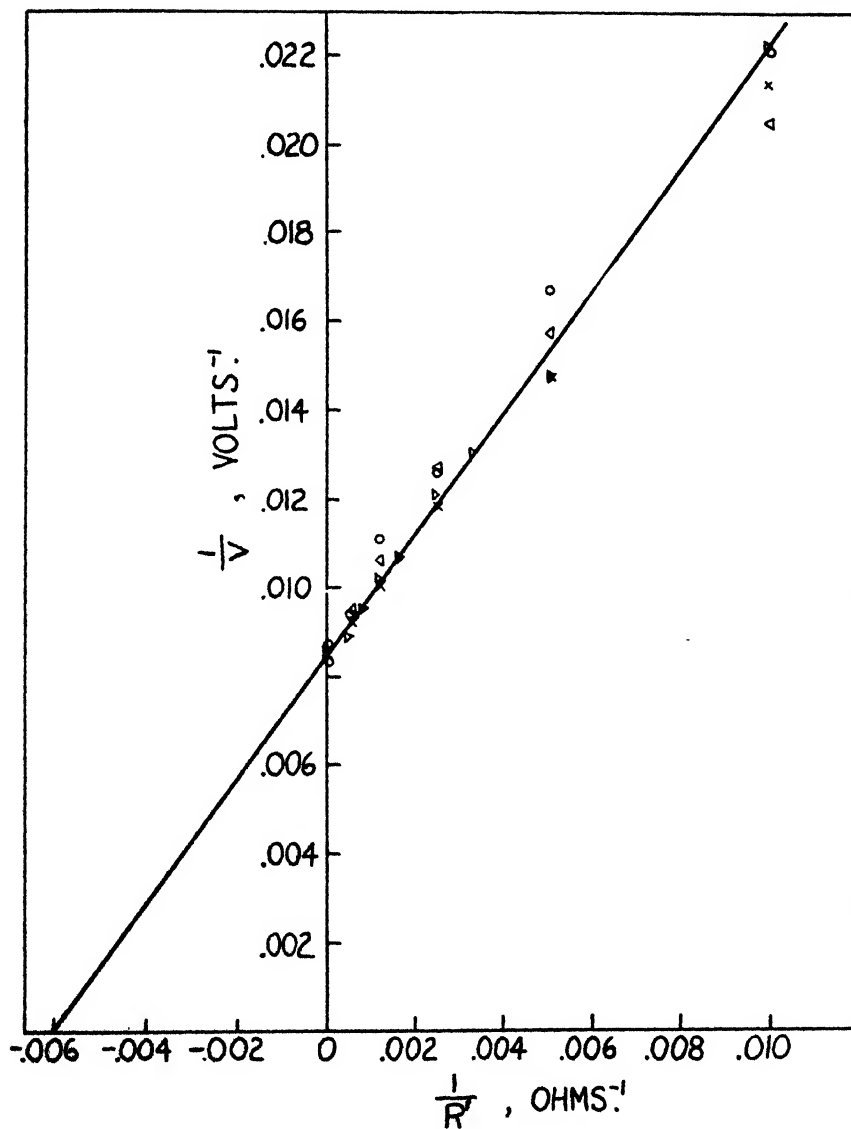
The results of these observations and computations are shown in Table I for the major discharge and Table II for the minor discharge. The distances recorded in the first column of each table are measured from the anterior end of the anal fin, which is a convenient point of reference almost at the anterior end of the large organ.

TABLE I.
Major Discharge.

Positions of Electrodes, cm.	r , ohms	R , ohms	E , volts
0, 10	750	175	160
10, 20	765	210	150
20, 30	725	210	130
30, 40	675	180	90
40, 50	600	215	60
50, 60	550	325	30
60, 70	625	605	22
&			
60, 80	1215	850	32

TABLE II.
Minor Discharge.

Positions of Electrodes, cm.	r, ohms	R, ohms	E, volts
30, 40	675	475	4.8
40, 50	600	365	7.7
50, 60	550	365	12
60, 70	625	475	20
70, 80	925	780	22



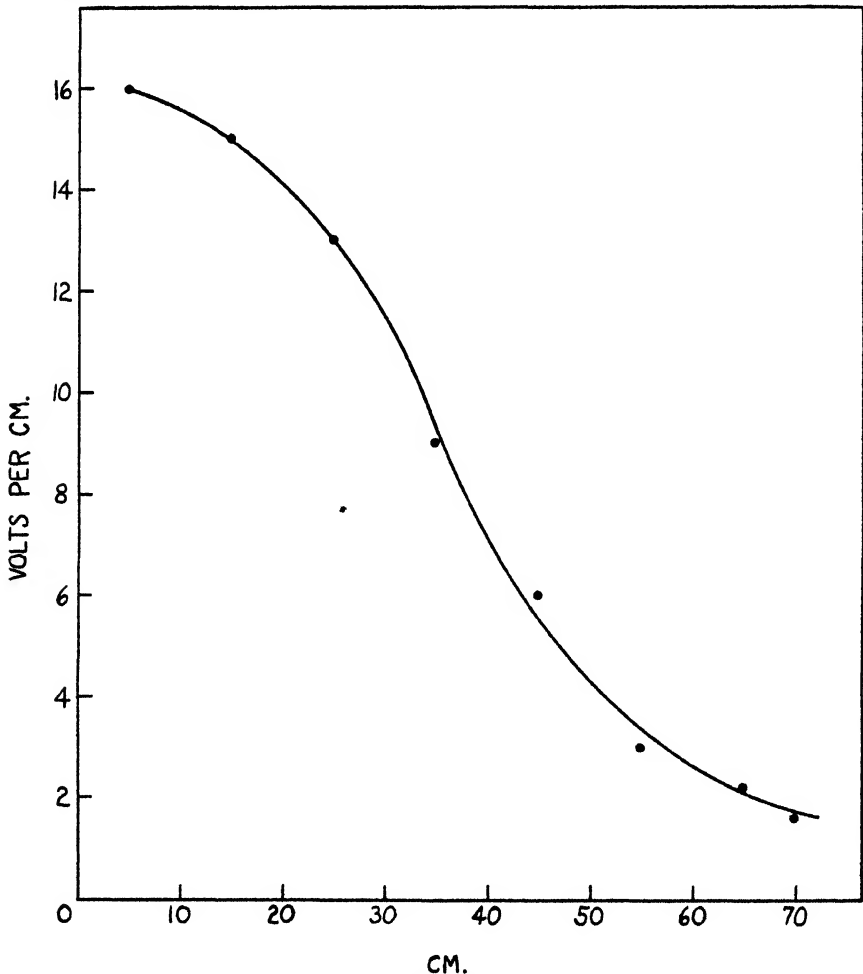
Text-fig. 1.

Major discharge. Electrodes at 10 cm. and 20 cm. from anterior end of anal fin. Reciprocal peak voltage vs. reciprocal external resistance.

It is hard to estimate the accuracy of these results. As regards the leakage resistance r , it is not so much the accuracy of the measurement itself which is in question as the accuracy of the assumption that all the current caused to flow in the adjacent tissue by the discharge of a segment of the organ can be treated as following a single path. As was pointed out in the paper already referred to³ and as must indeed be rather obvious, this can be only a crude approximation. The error in this assumption will impair the accuracy of the determination of the internal resistance R , which is subject also to the errors of the extrapolation in the graphical method illustrated in Text-fig. 1. In what follows we are principally interested in the electromotive force E . Its values are computed from the values of the resistances and the measured values of the peak voltage by the equation

$$E = V \frac{r+R}{r} \quad (4)$$

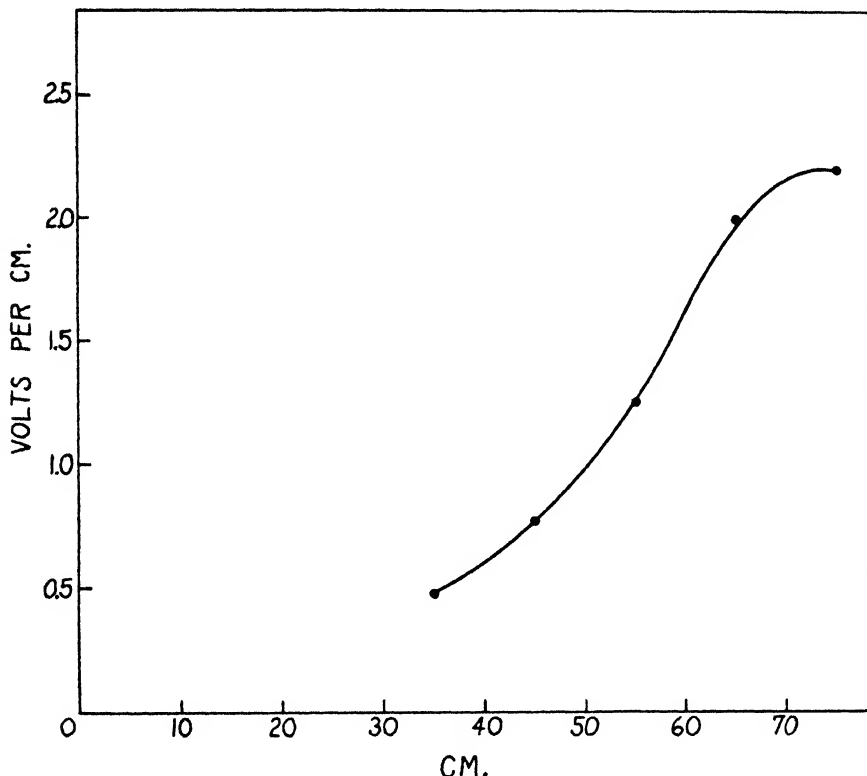
in which V is the peak voltage observed with no external conductor between the electrodes. It is seen in Table I that for about 50 cm. along the fish from



Text-fig. 2.

Major discharge. Electromotive force per cm. vs. distance along organs from anterior end of anal fin.

the anterior end of the large electric organ the measured values of r are much larger than the computed values of R in the major discharge. It seems probable that here the electromotive force actually is, as it is represented by the equation, not much greater than the peak voltage observed with no external conductor. In this case the ambiguities involved in the values of the resistances will not be very important in the determination of the electromotive force. We think it likely that the first five values of the electromotive force in Table I are not in error by more than about 10 per cent. The other values of Table I and those of Table II we consider rather more doubtful.



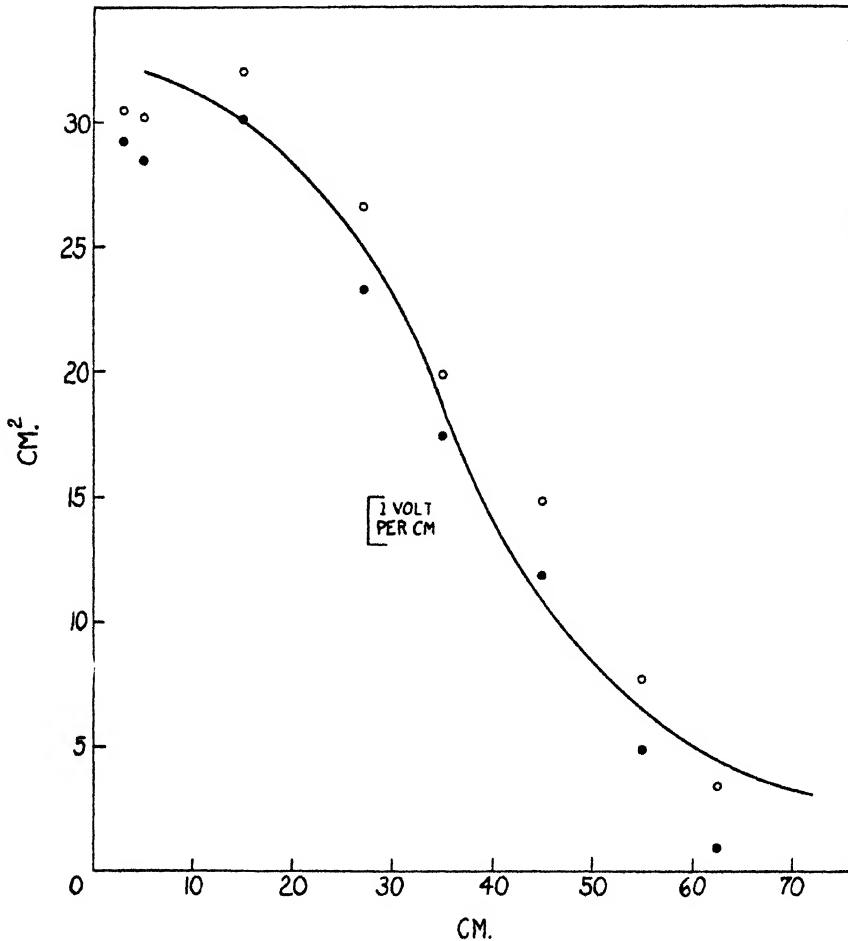
Text-fig. 3.

Minor discharge. Electromotive force per cm. vs. distance along organs from anterior end of anal fin.

In Text-fig. 2 the electromotive force per cm. of the major discharge, as reckoned from the data of Table I, is plotted as ordinate against the distance along the fish as abscissa. For plotting the first point on the left the average value of the electromotive force per cm. between electrodes at 0 and 10 cm. is taken as the value at 5 cm., and similarly for the other plotted points. Text-fig. 3 is a similar graph for the minor discharge plotted from the data of Table II.

After the measurements of the voltage and resistance were made, the fish was killed and its body transsected at a number of places. At these places the areas of the cross sections of the electric organs were measured. In Text-fig. 4 the black dots show the cross-sectional area of the large organ at various points along the fish, measured as in the other data from the anterior end of the anal fin. The white dots in the same figure show the sum

of the cross-sectional areas of the large organ and the organ of Hunter. For comparison the curve from Text-fig. 2, showing the electromotive force per cm. of the major discharge at points along the organ, has also been drawn in the figure, to the scale of volts per cm. indicated by the bracket. The fall of the plotted points along the curve is very striking. It is plain that there is a rather close proportionality between the electromotive force per cm. of the major discharge and the cross-sectional area either of the large organ alone or of the large organ and Hunter's organ together. Because of the small cross-section of Hunter's organ the ratio of area to electromotive force per cm. is not much different whether Hunter's organ be included or left out. In either case, for each 0.5 sq. cm. of cross-sectional area at any point there is found at the same point an electromotive force of approximately 1 volt per cm. along the axis of the organs. By varying the scale, either set of points can be brought closer to the curve than the other set. The best fit of the points which show the cross-section of both organs seems to be a little closer

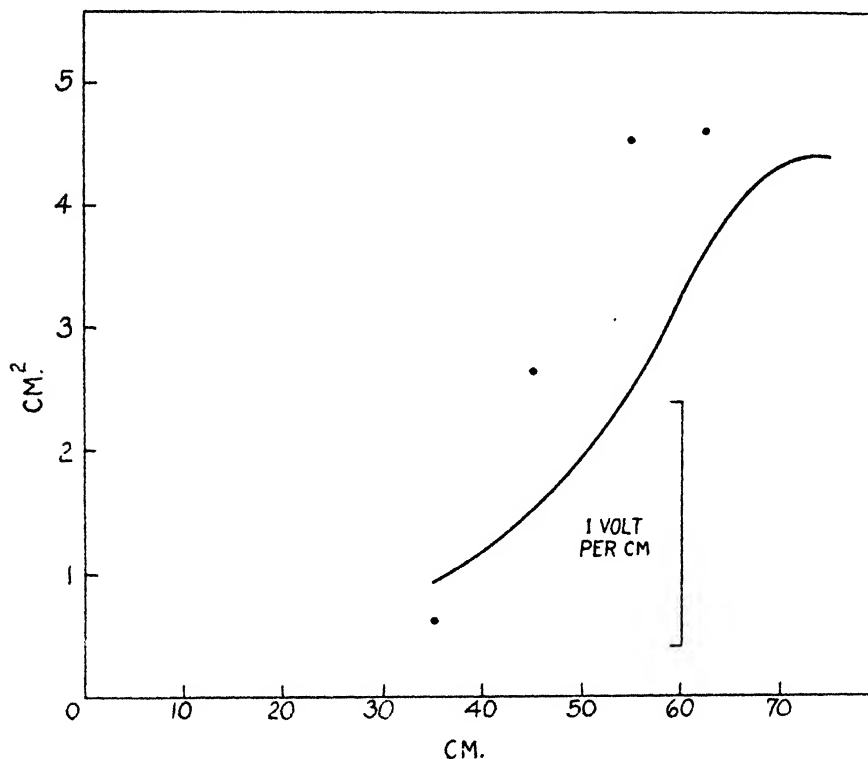


Text-fig. 4.

Curve: major discharge, electromotive force per cm. vs. distance along organs. Black dots: Large organ, cross-sectional area vs. distance along organs. White dots: Large organ and Hunter's organ, cross-sectional area vs. distance along organs.

than the best fit of the points showing the cross-section of the large organ alone, but there is not much to choose between the two.

The significance of this proportionality between the electromotive force per cm. and the cross-sectional area is not yet clear. If, in the discharge, the current were the same through every cross-section of the organ, then the observed relation would mean that equal quantities of power were generated in equal volumes of the electric tissue, since power is the product of electromotive force and current. But the current can scarcely be continuous along the organ when the fish discharges under water, since the whole skin is conducting.



Text-fig. 5.

Curve: minor discharge, electromotive force per cm. vs. distance along organs. Dots: Sachs' organ, cross-sectional area vs. distance along organs.

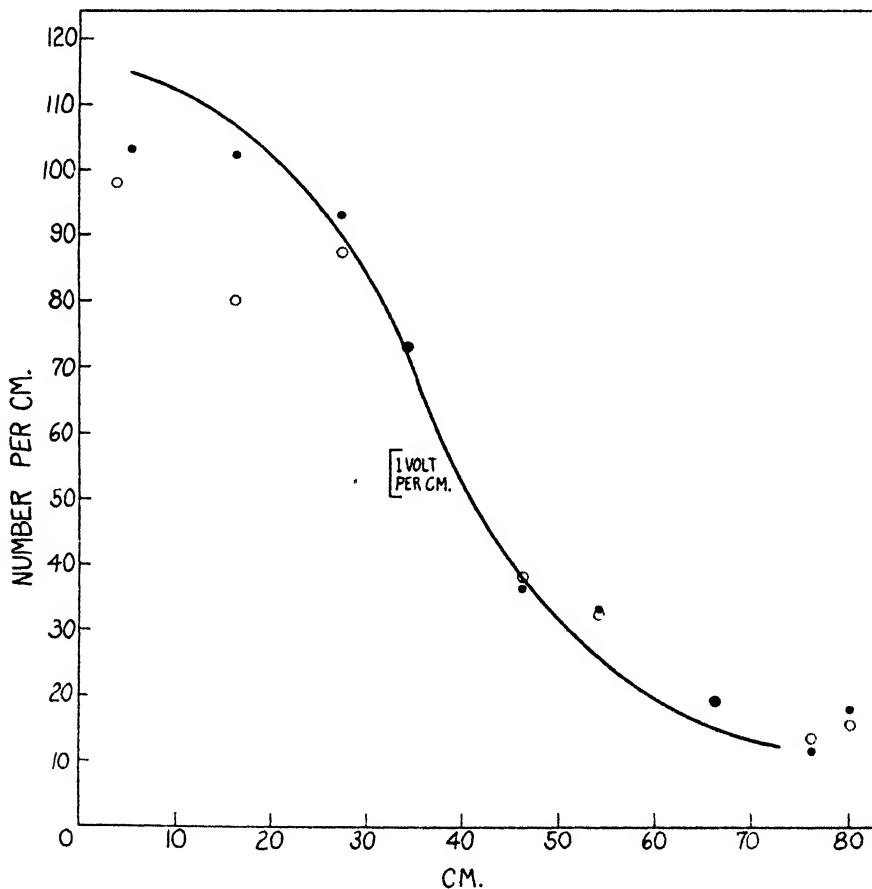
In Text-fig. 5, the plotted points show the cross-sectional area of the organs of Sachs and the curve shows the electromotive force per cm. of the minor discharge. The scales of area and electromotive force per cm. are not the same as in Text-fig. 4, but their ratio is the same. By choosing another value for this ratio, the points could be brought nearer to the curve, but the proportionality between the electromotive force per cm. and the cross-sectional area is by no means as clear as in the other case. On the other hand, the measurements are less dependable.

Transverse segments of the body of the fish were also divided sagittally, and the exposed surface of electric tissue was stained with methylene blue. The number of electroplaxes per cm. in the direction of the length of the fish, which is also the direction of the electric polarity, was counted under the microscope in each of the organs at various points along them. The septa of the electric tissue are tough but the matter they inclose is watery and

the tissue is therefore easily misshapen after being cut. This distortion of the cut surface could not be entirely prevented but was limited by mechanical means. The probable error of the count is estimated at less than 10 per cent along the greater part of the large organ and Hunter's organ, and somewhat more elsewhere.

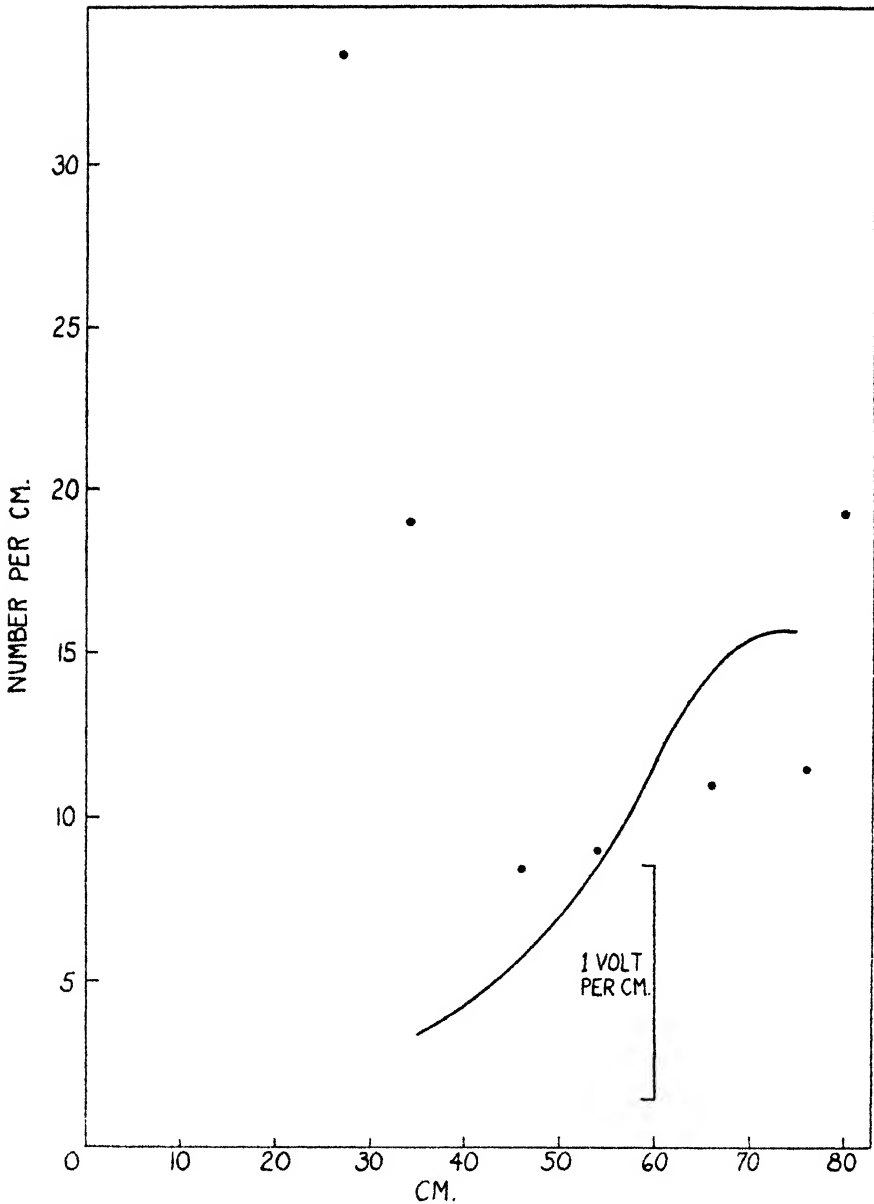
In Text-fig. 6, the black dots show the number of electroplaxes per cm. at various points along the large organ, and the white dots show the number per cm. along the organ of Hunter. Except at one place there is no difference between them too great to be a probable error of measurement. The curve showing the electromotive force per cm. of the major discharge is also drawn here for comparison. Again the plotted points fall rather close to the curve, and here the proportionality between the two plotted quantities has a clear enough meaning, which is simply that the electromotive force of one electroplax is at least roughly the same all along the organ. From the data plotted in Text-fig. 6 it is about 0.14 volt.

Dr. Kenneth S. Cole, using the needle technique, has found a change in potential during activity in the squid axon of 0.16 volt, and in *Nitella* of 0.1 volt. (Personal communication).



Text-fig. 6.

Curve: major discharge, electromotive force per cm. vs. distance along organs. Black dots: Large organ, number of electroplaxes per cm. vs. distance along organs. White dots: Hunter's organ, number of electroplaxes per cm. vs. distance along organs.



Text-fig. 7.

Curve: minor discharge, electromotive force per cm. vs. distance along organ.
 Dots: Sachs' organ, number of electroplaxes per cm. vs. distance along organs.

In the first of the papers referred to above², the opinion was tentatively offered that Hunter's organ produced the irregular discharge to which the name intermediate was given, the major and minor discharges being more positively ascribed to the large organ and Sachs' organ. But it was observed afterward and mentioned in the second paper³ that the power of the intermediate discharge seemed too great to be generated in Hunter's organ alone.

It was concluded therefore that Hunter's organ produced no separate discharge though it might possibly produce an irregularity in the discharge of the large organ. The similarity in the structure of adjacent parts of Hunter's organ and the large organ now leads us to question whether the large organ ever discharges alone, without Hunter's organ, or whether, on the contrary, Hunter's organ is functionally a part of the large organ, only separated from it by connective tissue and the remnant of the *lateralis imus*.

In contrast to Hunter's organ, which is clearly separated from the large organ but closely similar to it in structure, the organ of Sachs is hardly separated at all from the large organ but over much of its length is clearly different in the size of the electroplaxes. At the two ends of Sachs' organ, however, the electroplaxes are about as many to the centimeter as in the adjacent parts of the large organ, and appear, at least with the crude staining and under the low magnification employed in these observations, to be practically identical with them. Especially toward the posterior end the organs become indistinguishable, the septum between them being no more marked than the septa within each organ. Toward the anterior end the two organs remain distinguishable by the sizes of the electroplaxes, at least until a place is reached at which the cross-section of Sachs' organ is very small indeed, containing only a few electroplaxes in parallel.

As shown by the points in Text-fig. 7, the number of electroplaxes per cm. in Sachs' organ has by far its highest value at the anterior end, where the electromotive force per cm. is low, according to the measurements previously described. This is a surprising finding, as it would imply that the single electroplax of Sachs' organ in this part has a much lower electromotive force than the neighboring and similar electroplax of the large organ. This seems so unlikely as to require further evidence before it can be accepted.

Preliminary measurements leading to the work here described were made in 1937 at the Museu Goeldi of Pará, Brazil, by the New York Aquarium-New York University Expedition to study the electric eel. It is a pleasure to acknowledge again the generous grant to this expedition made by the Doctor Simon Baruch Foundation and to express again our thanks to Dr. Godofredo Hagmann of the Museu Goeldi and to many others who aided the research at that time. The present data were obtained at the Biological Laboratory of the Long Island Biological Association at Cold Spring Harbor. We are very grateful to Dr. Eric Ponder and others at the Laboratory for the help and encouragement we received from them.

INDEX.

Names in bold face indicate new genera, species or varieties; numbers in bold face indicate illustrations; numbers in parentheses indicate the paper containing the Plate numbers immediately following.

A

- Abylopsis** **tetragona**, 304
Acanthephyra, 133
 acutifrons, 146, **146**
 anomala, 185
 brachytelsonis, 147
 brevirostris, 148, **149**, 154
 cucullata, 150
 curtirostris, 143, **144**
 eximimia, 147, **148**
 gracilipes, 149, **150**, **151**
 haeckelii, 140, **141**
 indica, 150
 pulchra, 148
 purpurea, 134, **141**
 sibogae, 150
 sp. ? , 151
 stylorostata, 144, **145**
 tenuipes, 150
Acanthodoras sp. 549
Acharax, 375
Acila, 388
 (Truncacila) **castrensis**, 388
Acinonyx **jubatus**, 276
Acipenser **fulvescens**, 549
 oxyrhynchus, 549
Actinotheroe **californica**, 217, **217**, **218**
 undata var. **anguicomma**, 217
Adrana, 389
 arcuata, 407, 408
 cremifera, 407, 408
 elongata, 407, 409, (25) **Plate II**
 exoptata, 407, 409, (25) **Plate II**
 janeiroensis, 408
 newcombi, 410
 penascoensis, 407, 410
 scaphoides, 411
 sowerbyana, 407, 410
 suprema, 407, 409, 411
 taylori, 407, 412
 tonosiana, 407, 412, (25) **Plate II**
Aegina **citrea**, 313
Aeginura **beebei**, 309, **310-312**
 grimaldii, 289, 309, 313
Aequidens **moronii**, 549
Agapornis sp. 273
Agelaius **ruficapillus frontalis**, 273
Agkistrodon **blomhoffi**, 270
 mokasen cupreus, 270
 piscivorous, 50, 270
Aidemosyne **modesta modesta**, 274
Ailuropoda **melanoleuca**, 261
Aix **sponsa**, 275
Ajaia **ajaja**, 272
Alces **alces**, 469
Alicia **beebei**, 211
Allacanthochasmus **artus**, 550
 varius, 550
Alligator **mississippiensis**, 34
Allocreadium sp., 550
Alopochen **aegyptiacus**, 468
Amazona **barbadensis barbadensis**, 272
 festiva festiva, 273
 ochrocephala oratrix, 272
 panamensis, 272
Ambloplites **rupestris**, 549
Amblyrhampus **holosericeus**, 273
Ameiurus **melas**, 92
 nebulosus, 89, **91**, 92, 353, **355**, 549, 550,
 (8) **Plate I-VIII**
Amia **calva**, 549
Amnotragus **lervia**, 277, 278, 469
Amphicondrius **granulosus**, 337
Amphiodia **sculptilis**, 337
 urtica, 338
 vicina, 338, **338**
Amphipholis **geminata**, 336
 platydisca, 337
 squamata, 337
Amphura **arcystata**, 336
Amphostus **sabinus**, 550
Anas **crecca carolinensis**, 272
 platyrhynchos, 275, 468
 platyrhynchos, 275
 rubripes tristis, 275
Anguilla **japonica**, 264
Anodorhynchus **leari**, 273
Anoptichthys **jordani**, 113, (18) **Plates I-III**
Anthracoeros **malabaricus malabaricus**, 272
Anthracotheorax **violicauda violicauda**, 273
Anthropoides **paradisea**, 274
Apharyngostrigea, 323
 bilobata, 323 (20) **Plate I**
 brasiliana, 324
 cornu, 325
 egretti, 324
 flexilis, 325
 garciai, 325
 ibis, 325
 repens, 325
 (?) **simplex**, 325
Arbacia **incisa**, 348
Arca **adamsii**, 423
Arctocephalus **australis**, 277
Ardea **cinerea**, 325
 goliath, 272
 herodias herodias, 323, 325
 nigra, 326
 purpurea, 325
Ardeola **ibis ibis**, 325

- Argidia alonia*, 84
azania, 84
hilaris, 84
Argulus spp. 552
Argusiannus argus argus, 274
Arius aqua-dulce, 223
Arizona elegans elegans, 270
Asteroidea, 332
Astrapia rothschildi, 259
stephaniae stephaniae, 272
Astropecten armatus, 332
californicus, 332
Astropyga pulvinata, 348
Ateles cucullatus, 276
Atolla wyvillei, 315
Auripasser luteus, 274
Axis axis, 469
- B**
- Badis badis*, 549
Bagre marinus 221, **222**, **224**, **225**, **229**, **230**,
232, **234**, **236**, (13) **Plates I-V**
Balistes vetula, 549
Barbus lineatus, 549
Basiliscus vittatus, 34
Bentheocaris exuens, 145
Bianium plicatum, 550
Bitis gabonica, 271
Blarina brevicauda, 476, 477
Boa canina, 271
Boiga dendrophila, 270
Bothriocephalus cuspidatus, 551
Brachypternus benghalensis benghalensis, 272
Branchellion ravenelli, 551
Branta canadensis, 468
Brotopernis jugularis jugularis, 273
Bubo virginianus virginianus, 272
Bucephalus pusillus, 550
Bunocephalus bicolor, 549
Buteo jamaicensis borealis, 273
Bycanistes cristatus, 272
sharpii dubois, 273
- C**
- Calamoichthys calabaricus*, 549
Callinectes sapidus, 227
Calliobothrium verticillatum, 551
Callithrix penicillata, 277
Calycopsis bigelowi, 290
birulai, 290
borchgrevinki, 290
chuni, 290
geometrica, 290
nematophora, 290
papillata, 290
prolifera, 303
simplex, 290
simulans, 290, 293
typa, 290
valdiviae, 290
Camallanus sp., 551
Camelus dromedarius, 278
Campostoma, 2, 6
anomalum, 6, 11
pullum, 7, 9
Cancellaria cumingiana, 371
Cancroma cochlearia, 324
Canis latrans, 278
Carassius auratus, 501, 552
Carcharias littoralis, 551
Cardium magnum, 371
Ca restricta, 86
Carpodacus mexicanus frontalis, 273
Casmerodius albus egretta, 272, 273
Cathaemasia famelica, 327
hians, 326
nycticoracis, 323, 325, (20) **Plate I**
reticulata, 326
spectabilis, 327
Calostomus commersonnii commersonnii, 10
Cebus capucinus, 276
fatuellus, 466
Centromochlus aulopygius, 549
Cerastes cerastes, 270, 271
Cercocebus fuliginosus, 466
torquatus, 276
Cercopithecidae, 513
Cercopithecus grivet, 466
mona cambelli, 276
mozambicus, 466
sabaeus, 276, 466
Cervus axis, 276
canadensis canadensis, 276
duvauceli, 278
eldi, 277
elephas, 469
hortulorum, 277
unicolor, 277
Chaenobryttus gulosus
Chaetodipterus faber, 549
Channa asiatica, 549
Cheirodon piaba, 549
Chelydra serpentina serpentina, 47
Chiarella centripetalis, **294**, **295**
Chilodon sp., 550
Chilomycterus schoepfii, 550
Chlorophonia frontalis frontalis, 272
Chlorostilbon caribaeus caribaeus, 273
Choephaga magellanica, 468
Choeropsis liberiensis, 277
Chondranchthopsis nodosus, 551
Chromatonema erythrogonon, 297, **298**
hertwigi, 297
rubrum, 297
Chrysolophus pictus, 274
Cichlasoma festivum, 549
urophthalmus, 116
ericymba, 116
Ciconia alba, 326
ciconia ciconia, 273
Circus cyaneus hudsonius, 273
macrurus, 325
Cirrhitus aprinus, 58
graphodipterus, 58
Cirrhitichthys aureus, 61
corallicola, 58, 60
Cirrhitus, 54
betaurus, 55
rivulatus, 54, **56**, **64**, (5) **Plate I**
Clethrionomys gapperi, 477
Clinostomum campanulatum, 323, 327, 551
Clinostomus elongatus, 7
Clypeaster europacificus, 349
ochrus, 350

speciosus, 350
Coliuspasser albonotatus, 272
Colobonema typicum, 302
Columba constrictor constrictor, 36
Columba livia, 272
Constrictor constrictor constrictor, 270
Corallobothrium sp., 551
Corturnix corturnix, 467
Corvus brachyrhynchos brachyrhynchos, 274
Costelloeda, 398
Crepidostomum sp., 550
Crinifer piscator, 273
Crossobothrium iaciniatum, 551
Crossoptilon mantchuricum, 273
Crossophus fodiens, 484
Crotalidae, 49
Crotalus atrox atrox, 270
 cerastes, 271
 horridus atricaudatus, 270
 viridis viridis, 46, 270
Cryptocotyle lingua, 551
Ctenophthalmus pseudagyrus, 488, 490
Ctenops vittatus, 549
Ctenosaura acanthura, 271
Cunina proboscidea, 306
 prolifera, 303, 306
Cunoctona lanzerotae, 309
 mvosura, 311
 nausothoe, 309
Cyanerpes cyaneus, 275
Cyclochaeta domerqui, 550
Cygnus alor, 273, 468
Cyprinodontidae, 9
Cyrilla, 389
 adamai, 420
 munita, 419
 (*neopleurodon*) *subdolos*, 420

D

Dama dama, 277, 469
Dasyllus aruanus, 549
Dasyatis hastatus, 551
Dasyus novemcinctus texanus, 278
Dendroaspis augusticeps, 270
 viridis, 270
Dendrocygna autumnalis autumnalis, 275
 discolor, 275
Dendrolagus ursinus, 523
Didelphis virginiana, 276
Diodon hystrix, 549
Diopederma danianum, 343
Diplectanus sp., 550
Dissoura episcopus microcelis, 274
Distoma cornu, 324
Distomum simplex, 324
Dithaduma ? *domarita*, 87
Doratopsylla blarinae, 488, 490
Dromiceus novaehollandiae novaehollandiae, 275
Drosophila athabasca, 27
 azteca, 27
 lancefieldi, 26
 melanogaster, 27
 miranda, 27
 pseudoobscura, 23
Drymarchon corais couperi, 270

Echinometra vanbrunti, 349
Elaphe obsoleta obsoleta, 37
 quadrivittata quadrivittata, 270
 vulpina, 38
Electrophorus electricus, 249, 553, (14) **Plate I**
Ennucula, 382
Ephyrina, 173
 bifida, 174
 hoskynni, 173
Epibdella melleni, 526, 550
Epicrates cenchris, 271
Epinephelus striatus, 549
Ergasilidae (Spp?), 552
Ergasilus sp., 552
Erithizon dorsatum dorsatum, 277
Erythrocebus patas, 278
Esomus malayensis, 549
(Esox), *estor*, 551
Esox lucius, 2
 masquinongy, 549
Etiopius suratensis, 549
Eucidaris thouarsii, 347
Euglyphis marbodia, 85
Eumedusa similis, 290
Eunectes murinus, 270
Euphractus sexcinctus, 277
Euplectes franciscana franciscana, 273
 erix erix, 275
Eupomotis gibbosus, 353, 354, 550, (23) **Plates I, II**
Eutara mayeri, 284
Exoglossum, 4, 8
 maxilliqua, 6, 7, 11

F

Felis cacomith, 278
 cougar, 276
 leo, 278
 pardalis, 276
Florida caerulea, 272
Forbesella (Chologaster) agassizii, 115
Fundulus bermudae, 97, 98, 99, 100
 heteroclitus, 550

G

Galago alleni, 436
 crassicaudatus, 436
 montieri, 440
 demidoffii, 436
 senegalensis moholi, 433, (27) **Plates I-VI**
Galeichthys felis, 221, 222, 225, 229, 230, 232, 234, 236, 549, (13) **Plates I-V**
 milberthi, 235
Gallus gallus, 467
 gallus, 273
Gambusia affinis, 501
 affinis, 108
 holbrooki, 97, 99, 106, 107, 109
Gennaeus leucomelanos melanotus, 274
 nyctimerus, 467
 swinhoni, 467
Ginglymostoma cirratum, 549
Gonostoma elongatum, 127, 136, 175
Gorilla berengei, 519
 gorilla, 513
Grus canadensis tabida, 275

Guttera edouardi edouardi, 272
Gymnoderus foetidus, 274
Gymnothorax funebris, 549
 moringa, 549
Gymnotis coatesi, 549

H

Halichaeres radiatus, 549
Halicreas minimum, 302
Hapale pygmaea, 276
Harengula pensacolatae, 22
Helioperca macrochura, 549, 550
Heloderma horridum, 271
 suspectum, 271
Hemitragus jemlahicus, 276
Hemixus flavala flavala, 275
Henneguya acerinae, 92
ameiurensis, 89, 90, 91, 92, 552, (8) **Plates**

I-VIII

exilis, 93
gurleyi, 92
Herichthys cyanoguttatus, 549
Herodias timorensis, 325
Holostomum repens, 324
Huro salmoides, 549, 551
Hybognathus regius, 10
Hyborhynchus notatus, 551
Hyelaphus porcinus, 470
Hylesia dERICA, 85
Hymenodora glacialis, 176, 179
 gracilis, 175, 176
Hyphessobrycon heterohabdus, 549
 serpae, 549

I

Ichthyophthirius multifiliis, 527, 550
Ictalurus punctatus, 93, 551
Iguana iguana rhinolapha, 270
Ilyoplax pusillus, 66

J

Jupiteria, 402

K

Kakatze galerita galerita, 274
 roseicapilla roseicapilla, 274
 sanguinea goffini, 274
Katadesmia, 413
Kittocincla malabarica malabarica, 274
Koiprotamus koiprotamus kenlae, 277

L

Lagothrix humboldtii, 277
 ingumatus, 277
Lama vicugna, 278
Lamprolepis getulus floridana, 40, 270
 geiulus, 271
 splendida, 271
 subsp., 270
Larus argentatus smithsonianus, 273
 atricilla, 274
 novae-hollandiae novae-hollandiae, 274
Lebistes, 98
 reticulatus, 99, 109, 110, 111
Lecithaster lindbergi, 264
Leda agapea, 394
 electa, 412
 fortis, 402

inornata, 404
metacalfi, 408
pontonia, 403
sowerbyana, 411
taylori, 411

Lepisosteus osseus, 549

Lepomis auritis, 329, 364, 549 (21) **Plate I**

cyanellus, 364
Leptochela bermudensis, 131, 132
Leptoptilus crumenifer, 327
Leptotila cassini cassini, 274
Lernae sp., 552
Lernaenicus radiatus, 551
Leuckarthara gardineri, 284
zaca, 284, 285, 286
Leucosomus corporalis, 6, 7, 11, 363
Leucotmetus kaletura, 87
Ligula intestinalis, 551
Linckia colombiae, 334
Lintonium vibex, 550
Liriope tetraphylla, 302
Lophortyx californica californica, 274
Lophura rufa, 273
Lovenia cordiformis, 352
Lucaya bigelowi, 189, 190
Luidia asthenosoma, 332
 bellonae, 332
 foliolata, 333
 ludwigi, 333
Lutra canadensis vaga, 277
Lytechinus anamesus, 348
 pictus, 348

M

Macaca irus, 276, 466, 513
 mulatta, 276, 466, 515
 nemestrina, 276
Macaria barticaria, 86
Macrophthalmus depressus, 66
 dilatatus, 66
 japonicus, 66
Macropus giganteus giganteus, 277
Malletha, 389, 420
 elongata, 422
 faba, 423
 gigantea, 421
 inequalis, 423
 magellanica, 424
 (Malletia) chilensis, 421
 (Minormalletia) arciformis, 423
 (Minormalletia) benthina, 423
 (Neilo) goniura, 422
 patagonica, 424
 peruviana, 424
 truncata, 424
Medusa mollicina, 304
 pilearis, 304
Megaceryle alcyon, 326
Megalaima virens marshallorum, 274
Megayoldia, 414
Meleagris gallopava silvestris, 272
Melopsittacus undulatus, 274
Melozona leucotis, 272
Menidia menidia, 551
Meningodora mollis, 165
Meoma grandis, 352
Mephitis nigra, 276

- Microcotyle* sp., 550
Microglanis parahybae, 549
Microgonia hildonia, 87
Micropterus dolomieu, 551
Microtus pennsylvanicus, 477
Minormalletia, 422
Moenkhausia pittheri, 549
Moiria clotho, 350
Mollienisia sphenops, 98, 99, 101-105
 ssp., 104
Monolepis albicans, 67
 inermis, 66, 67, 70, 81
 orientalis, 67
Morone interrupta, 549, 550
Mugil curema, 237
Munia atricapilla atricapilla, 274
Muntiacus muntjak, 469
Murex recurvirostris, 217
Musophaga violacea violacea, 274
Mustelus canis, 551
Myadestes unicolor, 275
Mycteroperca bonaci, 549
Mylossoma duriventris, 549
Myxobolus cf. *linearis*, 92
 sp., 550
- N**
- Naja hannah*, 27
 naja, 270
 nivea, 270
Napaiozopus insignis, 477
Narcine brasiliensis, 431
Nasua nasua, 276
Natrix cyclopion floridana, 42
 erythrogaster transversa, 43
 septemvittata, 44
 sipedon pichventris, 45
 sipedon, 9
Neascus vancleavei, 551
Neila, 422
Nemanthidae, 212
Nemanthus, 212
 californicus, 214, 215, 216
 nitidus, 213, 214, 216
Nematobothrium sp., 550
Neochasmus umbellus, 550
Neopleurodon, 419
Neoturris crockeri, 287, 287-289
Nidorellia armata, 333
Nocomis, 2, 6, 7
 biguttatus, 6, 361
 micropogon, 6, 361
Notemigonus crysoleucas, 495
Notopser curaeus, 274
Notophoxys novaehollandiae, 325
Notostomus, 152
 beebel, 168
 compsus, 156, 157
 distirus, 166, 167
 fragilis, 165
 gibbosus, 170
 japonicus, 168
 longirostris, 172
 marpochales, 158, 159, 160
 miccylus, 161, 162, 163
 mollis, 164, 165
 murrayi, 168
 patentissimus, 172
 perlatus, 170, 171
 robustus, 168, 169
 vescus, 153, 154
 westergreni, 171, 172
Notropis cornutus, 1, 361, (1) **Plates I-IV**
 chrycephalus, 2, 5, 10
 cornutus, 1, 5, 362
 frontalis, 2, 4
 hudsonius hudsonius, 10
 pilsbryi, 361
 x rubellus, 7, 361, 362
Nuculopsis, 383
Nucula, 379
 abrupta, 422
 agujana, 379, 384
 cahuitensis, 381
 chrysocoma, 380, 385
 colombiana, 379, 385
 crenulata, 380
 darwinii, 411
 dorbigny, 408
 (Ennucula) cardara, 379, 383
 (Ennucula ?) linki, 379, 383
 (Ennucula) tenuis, 379, 382
 grayi, 379, 385
 hilli, 384
 iphigenia, 380, 386
 lanceolata, 411
 miliaris, 418
 (Nuculopsis) **schencki**, 384, (25) **Plate I**
 (Nucula) declivis, 380, (25) **Plate I**
 (Nucula) exigua, 380, 381
 obliqua, 382
 panamina, 379, 386
 paytensis, 380, 381, 386
 pigafettae, 380, 386
 pisum, 379, 387
 proxima, 427
 savatieri, 379, 387
 schencki, 380
 semiornata, 380, 387
 suprastriata, 380
 taeniolata, 380, 387
 tanneri, 379, 388
Nuculana, 378, 390
 acapulcensis, 394, (25) **Plate I**
 acrita, 391, 402
 agapea, 391, 402
 bicosata, 391, 394, 402
 cestrota, 399
 cordyla, 390, 401
 (Costelloleda) costellata, 390, 398, (25)
 Plate II
 (Costelloleda) **marella**, 390, 399, (25) **Plate II**
 crispa, 391, 403
 cuneata, 391, 403
 elaborata, 401
 excavata, 391, 404
 flexuosa, 399
 hamata, 390
 hindsii, 391, 404
 lobula, 392, 404
 loshka, 390, 404
 lucasana, 392, 405
 lyrata, 395
 media, 394
 ornata, 391, 405

oxia, 391, 405
 peruviana, 390, 405
 (Politolida) polita, 391, 394
 pontonia, 391, 406
 pyriformis, 394
 rhytida, 392, 406
 (Saccella) acuta, 390, 392, (25) **Plate I**
 (Saccella) callimene, 391, 393, (25) **Plate I**
 (Saccella) eburnea, 391, 395, (25) **Plate II**
 (Saccella) elenensis, 391, 393, 394, (25) **Plate I**
 (Saccella) gibbosa, 392, 395, (25) **Plate II**
 (Saccella) impar, 391, 396, (25) **Plate II**
 (Saccella) laeviradiata, 391, 396, (25) **Plate II**
 (Saccella) taphria, 391, 397
 (Spinula) calcar, 391
 (Spinula) calcarella, 391
 (Thestylida) cordyla, 400
 (Thestylida) hamata, 400, (25) **Plate III**
 Nuculidae, 378
 Nuculanidae, 389
 Nycticorax nycticorax hoaciti, 323, 325
 Nymphicus hollandicus, 274

O

Ocypode, 65
 albicans, 66, 69, 70, **71, 74-80**
 gaudichaudii, 66, 67, **68, 75, 77-80**
 occidentalis, 66, 69, 70, **74-80**
 Odocoileus virginianus leucurus, 470
 nemoralis, 469
 osceola, 276
 Oodinium ocellatum, 536, 550
 Ophedrys aestivus, 35
 Ophiactis savignyi, 339
 simplex, 340
 Ophiocoma aethiops, 341
 alexandri, 341
 Ophioderma panamense, 341
 teres, 342
 variegatum, 343
 Ophiopsis fulva, **345**
 grisea, **346**
 variegata, 344
 Ophiomyxa panamensis, 336
 Ophionereis annulata, 340
 nuda, 340
 Ophiophragmus, 338
 Ophiopteris papillosa, 341
 Ophiorthela gracilis, 340
 Ophiorthrix spiculata, 340
 Ophiozona pacifica, 344
 Ophisaurus apodus, 35
 Ophiura lutkenii, 343
 Opisthonema oglinum, 227
 Oplophorus, 132, 184
 foliaceus, 185
 gracilirostris, 188
 grimaldii, 187, **188**
 spinicauda, 184, **185**
 Oreaster occidentalis, 333
 Orthoyoldia, 414
 Ostnops viridis, 272
 Othilia aculeata, 334, (22) **Plate I**
 Otobothrium crenacolle, 551
 Otolcnus garnetti, 442
 Ovalipes ocellatus, 227
 Padda oryzivora, 275
 Pandarus bicolor, 551
 Pandea conica, 284
 rubra, 287
 Papio anubis, 276
 papio, 466
 Paracalops, 477
 breweri, 489
 Paradisaea guilhelmi, 273
 Paradoxurus hemaphroditus, 278
 Parapandalus, 192
 richardi, **192**
 zurstrasseni, 194
 Paroaria nigrigenis, 274
 Parotia lawesi lawesi, 257, 273
 sefilata, 257
 wahnesei, 257, **257, 259**
 Parapasiphae, 126
 macrodactyla, 126, **128, 129**
 sp. a, 126, **129**
 sp. b, 126, **130**
 sulcatifrons, 126
 Pasiphaea alcocki, 123
 amplidens, 126
 corteziana, 123
 hoplocerca, **124, 125**
 liocerca, 122, 123
 longispina, 123, 126
 orientalis, 126
 rathbunae, 123
 scotiae, 123, 126
 Patria miniata, 333
 Pavo cristatus, 275, 467
 var., 274
 Pegantha clara, **305, 306**
 martagon, 308
 smaragdina, 305
 triloba, 308
 Pegasus dodecagona, 304
 Pelagia noctiluca, 315
 Pelecypoda, 373
 Penella instructa, 551
 Perca flavescens, 549, 551
 Periphylla hyacinthina, 314
 Peromyscus, 22
 leucopus noveboracensis, 477, 489
 maniculatus, 489
 Petrusmus, 377
 Phalacrocorax auritus auritus, 327
 Pharia pyramidata, 334
 Pharomachrus mocinno mocinno, 273
 Phasianus colchicus versicolor, 274
 Phassus guianensis, 88
 Phastolomis mitchelli, 277
 Phataria unifascialis, 335
 Philortyx fasciatus, 274
 Photostomias guernei, 127
 Phytocaris microphthalmia, 196, **197, 198**
 Pionites melanocephala melanocephala, 274
 Pitta sordida cucullata, 274
 Pituophis melanoleucus melanoleucus, 39, 271
 sayi, 270
 Pitmyms pinetorum scalopsoides, 477
 Placobdella parasitica, 551
 Plagiobrissus grandis, 351
 pacificus, 351, (22) **Plate I**

Plagusia depressa tuberculata, 66, 70, 72

Plectropterus gumbensis niger, 273

Plesionika martha, 190, 191

Plethodon cinereus, 481

Pleurodon, 418

adamsii, 418

cinctus, 418

dobergensis, 418

gunteri, 418

hedleyi, 418

microdus, 418

ovalis, 419

woodi, 418

zinnborfi, 418

Ploceus vitellinus vitellinus, 275

Pocillopora, 342

Poecilidae, 97

Podocotyle atmon, 265

atzi, 263, 265, **266**, 550 (17) **Plate I**

Pogonias cromis, 549

Politoleda, 397

Polycolpa forskalii, 303

Polyorchis penicillata, 296

Polyxenia cyanostylis, 304

Pomoxia sparoides, 549

Pongo pygmaeus, 466

Pontobdella muricata, 551

Poionotus tricanthus, 551

Porpnayio poliocephalus poliocephalus, 272

Potos flavus, 278

Prepiella deicoloria, 88

Prionotus scitulus, 227

Pristella tiddlei, 549

Procavia capensis, 277

Probiotremia sp., 550

Protocephalus pinguis, 551 (33) **Plate V**
sp., 551

Prottrichomonas sp., 550

Pseudbarydia elipha, 83

Pseudemys floridana ssp., 48

Pseudocirrhulus, 53

pinos, 61, **62**

Psittacula eupatria nipalensis, 274

Psittacus erithacus erithacus, 273

Phlinopus jambu, 273

Ptyas mucosus, 270

Pucrasia macrolopha macrolopha, 272

Python curtus, 270

molurus molurus, 270

regius, 271

reticulatus, 270

R

Ramphostos discolorus, 274

piscivorus brevicarinatus, 272

swainsonii, 273

Ramplocelus carbo carbo, 275

Rasbora maculata, 549

heteromorpha, 549

trilineata, 549

Rhinocythys atratulus atratulus, 9, 10, 14 (1)

Plates II-IV

catatactae, 7

Rhinocheilus lecontei, 41

Rhodeus amarus, 353

Rhynchotus rufescens rufescens, 275

Rhynchotus jubatus, 273

Rhyticeros subruficollis, 272

Roccos lineatus, 549

saxatilis, 237

Rubigula dispar, 274

Rypiticus saponaceus, 549

S

Saccella, 392

Sagittarius serpentarius, 272

Saiga tatarica, 277

Salvelinus fontinalis, 549

Sarcophilus harrissii, 276

Sarda sarda, 550

Scaphirhynchus platyrhynchus, 549

Scardinius erythrophthalmus, 549

Scatophagus argus, 549

Schizoderma diplax, 343

Sceleporous undulatus fasciatus, 34

Sciaenops ocellatus, 549

Sclerasterias alexandri, 335

crassia var., 335

heteropaes, 335

var., 335

Scopimera globosa, 66

Scorpaena madurensis, 263, 264, 265, 550, (17)

Plate I

Scyllarides latus, 551

Sebastes marinus, 551

Semotilus, 2, 6, 7

atromaculatus atromaculatus, 6, 7, 9, 11, 14

(1) Plate I

Seriola zonata, 549

Serranus cabrilla, 237

Serrasalmus scapularis, 549

Sigsbeia lineata, 336

Sika nippon, 468

Simudi, 513

Solemya, 374

(*Acharax*) *agassizii*, 375

(*Acharax*) *dalli*, 375

(*Acharax*) *johnsoni*, 376

(*Acharax*) *macroductyla*, 376

(*Acharax*) *patagonica*, 376

australis, 374

borealis, 377

mediterranea, 374

parkinsonii, 374

(*Petrasma*) *panamensis*, 377

(*Petrasma*) *valvulus*, 378

(*Solemya*) *lomitensis*, 374

tokunagai, 376

yessoensis, 376

Solemyarina velesiana, 374

Solenella gigantea, 421

Solenodon paradoxus, 276

Solmissus albescens, 308

incisa, 308

marshalli, 308

Sorex araneus, 473

granti, 473

cinereus, 474

dispar, 474

fumeus fumeus, 473 (20) **Plates I-IV**

minutus, 485

vulgaris, 480

Sparus macrocephalus, 264

Spheroides maculatus, 550

Sphyrion lumpi, 551
Sphyrna zygaena, 551
Spinitectis sp.,
Spinula, 401
Spinus tristis tristis, 274
Stephanopropoides, 326
Sternotherus odoratus, 47
Sterrhurus branchialis, 550
Stizostedion vitreum, 550
Stomolophus agaicus, 316
 meleagris, 316
Stomotoca divisa, 283
 pterophylla, 283
Streptopelia decaocto decaocto, 272
Strongylocentrotus purpuratus, 349
Storeria dekayi, 41
Stylocidarid dubius, 347
Suricata suricatta, 277
Sylvicapra grimmii, 277
Symbranchus marmoratus, 549
Synaptomys cooperi, 477
Systellaspis, 179
 braueri, 180
 debilis, 181, 195
 densispina, 180
 echinurus, 180

T

Tachysurus barbus, 227
Taeniopygia castanotis castanotis, 275
Tangara arthus, 272
 cyanoptera, 273
 cyaneicollis hannahiae, 272
 flava cayana, 273
 guttata guttata, 275
 heinei, 272
 icterocephala, 274
 larvata centralis, 273
 mexicana mexicana, 273
 violacea violacea, 273
 xanthogaster exsul, 275
Tarpon atlanticus, 493, 549 (30) **Plates I, II**
Tautoga onitis, 551
Taxidea taxus taxus, 276
Taxus canadensis, 476
Terrapene carolina carolina, 4
Testudo formeri, 48
Thalassoma bifasciatum, 549
Thamnophis sirtalis sirtalis, 46
Theristicus caudatus, 274
Theslyleda, 400
Thraupis cana cana, 274
Tiliapia mossambica, 549
Tindaria, 389, 425
 amabilis, 426
 atossa, 426
 compressa, 426
 mexicana, 427
 panamensis, 426
 salaria, 427
 smurna, 427
 thea, 427
 (*Tindariopsis*) *sulculata*, 425
 virens, 428
Tindariopsis, 425
Tolyte loisa, 85

Taxopneustes roseus, 349
Trachinotus glaucus, 549
Tragelaphus angasi, 276
Tragopan caboti, 273
Trichechus manatus latirostris, 550
Trichiurus lepturus, 550
Trichodina sp., 550
Trichoglossus haematomoluccanus, 274
Tridacna gigas, 373
Trimeresurus flavomaculatus, 270
Truncacila, 388
Tubulovesicula anguillae, 264, 265
 angusticauda, 265
 californica, 264, 265
 lindbergi, 265
 madurensis, 263, 264, 265, 550 (11) **Plate I**
 muraenesocis, 264, 265
 pseudorhombi, 264, 265
 spari, 264, 265
Tupinambis teguixin, 271
Turdus merula merula, 272
 olivaceus olivaceus, 274
Tyto alba pratincola, 272

U

Uca minax, 66
 pugilator, 66
 pugnax, 66
Uraeginthus bengalus bengalus, 273
Urobrachya axillaris axillaris, 273
Ursus arctos arctos, 277

V

Varanus sp., 271
Venadicadia cettiona, 86
Vipera russelii, 270

X

Xenomystus nigri, 549
Xiphias gladius, 551

Y

Yoldia, 389, 412
 emersoni, 414
 (*Katadesmia*) *vincula*, 413
 (*Megayoldia*) *martyria*, 414
 (*Orthoyoldia*) *panamensis*, 415
 subaequilateralis, 421
 thracoeiformis, 416, 421
 (*Yoldiella*) *cecinnella*, 416
 (*Yoldiella*) *chilenica*, 416
 (*Yoldiella*) *dicella*, 416
 (*Yoldiella*) *granula*, 416
 (*Yoldiella*) *indolens*, 417
 (*Yoldiella*) *infrequens*, 417
 (*Yoldiella*) *leonilda*, 417
 (*Yoldiella*) *mantana*, 417
Yoldiella, 415

Z

Zalophus californicus, 277
Zapus hudsonius, 477
Zonurus giganteus, 270
Zygocanna costata, 301
 pleuronota, 301
 vagana, 299, 300
Zygocannula, 301

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